GRIGORE T. POPA UNIVERSITY OF MEDICINE AND PHARMACY IASI

HABILITATION THESIS

TECHNOLOGICAL PERSPECTIVES ON THE POSSIBILITIES AND LIMITS OF PROSTHETIC TREATMENT

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Contents

Abreviations

AAPHD- American Association of Public Health Dentistry
ADA –American Dental Association
ADP- Academy of Denture Prosthetics
AgNPs- Silver nanoparticles
AFM-Atomic Force Microscopy
AI- Artificial Intelligence
AR-Artificial Reality
CAD- Computer Aided Design
CAM- Computer Aided Manuifacturing
CBCT- Cone Beam Computer Tomography
CD- Complete Denture
CFU- Colony-Forming Units
DCS- Differential Scanning Calorimetry
EBM- Electron Beam Melting
HCR- Heta Curing Resin
FEA- Finite Element Analysis
IT- Information Technology
ML- Machine Learning
MMA- Methyl methacrylate
NIDR- National Institute of Dental Research
OM-Optical Microscopy
OSHA- Occupational Safety and Health Administration
PEEK- Polyetheretherketone
PMMA- Poly Methyl methacrylate
RP- Rapid Prototyping
SCR- Self-Curing Resin
SEM-Scanning Electrone Microscope
SLM– Selective Laser Melting
SLS- Selective Laser Sintering
TGN- Total Germs Number
VR -Virtual Realitity

ABSTRACT

The habilitation thesis, which summarizes my postdoctoral professional, academic and scientific activity, is framed in three major sections, according to the CNATDCU recommendations: Section I - Scientific achievements in the post-doctoral period; Section II - Future plans of development on scientific and academic career; Section III - Bibliographic references.

The paper entitled "**Technological perspectives on the possibilities and limits of prosthetic treatment"** reflects the overview of my concerns in the fields of technologies and materials for removable dentures, as well as the possibilities of optimizing their biomechanical parameters.

In the Section A, I made a short presentation of the professional, academic and scientific achievements of my entire teaching career, started in 1994.

After finishing my doctoral studies, I continued my research, broadening my area of interest on other types of prosthetic constructions and thus outlined the subsequent study directions, on which I focused since 2005 to the present: possibilities for optimizing the bio-mechanical properties of inlay type prostheses, optimizing the structure and quality of materials used in fixed prosthetic realization, possibilities to optimize the characteristics of acrylic removable ptoteseses, the economic aspects in the practice of dentistry, possibilities and limits of cross-infection control.

The habilitation thesis sums up the research on the increase of the performances of the acrylic resins used in the realization of mobile prostheses and the optimization of the activity in the dental laboratory.

Section B systematizes the postdoctoral scientific researches on which I focused in the 16 years of academic activity and is structured on three research fields. This section of the thesis contains the most relevant articles from my scientific activity, indexed in the Web of Science Core Collection and in international databases.

The first chapter of this section, entitled "Research on the characteristics and biomechanical behavior of acrylic resins for full dentures" includes researches specific to the field of Prosthesis and Dental Materials Technology, preceded by an introductory section, which details the latest and most relevant information on these topics.

The first direction of study is represented by researches on the characteristics and biomechanical behavior of acrylic resins for full dentures, following the behavior of these materials, after their optimization with silver nanoparticles, in order to prevent prosthetic stomatitis

The second research direction analyzes the effect of silver nanoparticles incorporation on structure and surface of the acrylic dental resins; knowing that the structure and surface quality of prosthetic constructions influence the adaptation and longevity of removable dentures, the studies aimed to analyze whether the introduction of silver nanoparticles, a procedure widely agreed by practitioners, significantly changes the structure and implicit behavior of acrylic resins.

The third direction focused on analyzing the surface characteristics of conventional dental acrylic resins, self-cured and heat- cured, depending on the finishing and polishing technique. The conclusions of the studies offer practical solutions to dental technicians, guiding them in choosing the optimal method and tools for processing, depending on the type of resin.

The second chapter entitled "Technological possibilities for full dentures realization" is also preceded by an introductory section which presents the conventional and modern methods used to make full dentures, as well as the advantages and disadvantages of the materials used in the technologies for these prosthetic constructions, longevity of these prostheses and the possibilities for a correct restoration of dento-maxillary system functions.

The first research direction is represented by studies on the main technologies for complete dentures, analyzing which are the methods most frequently used in practice for the realization of these devices.

The second research direction follows the analysis of the mechanical parameters of the complete dentures realized by different polymerization technologies. The polymerization mechanism influences the mechanical characteristics and the biological behavior of the acrylic resins. Our researches allowed the systematization of the optimal polymerization conditions, in order to obtain removable dentures with optimal parameters.

The third direction focused on the „Students' attitude regarding the implementation of digital technologies in current dental practice". All modern prosthetic restorations have a lot of advantages, but there are also many disadvantages which must be well known, in order to choose a correct therapeutic solution. To this end, our studies focused on analyzing the opinions of students from Dental Technician Specialization, on the implementation of digital technologies in dental laboratory activity, as well as the impact that these methods could have on the current practice.

The third chapter entitled ″The importance of clinical evaluation and materials used in prosthetic treatment" analyzes the importance of local and loco-regional factors in choosing therapeutic solution, as well as the impact of the design and the materials of the prosthetic constructions on the oral status.

First direction of this study focuses on Type II Diabetes Mellitus (DM) patients with periodontitis; The changes at the oral level determined by the alteration of the hormonal balance in women, in the postmenopausal stage. It was also emphasized the impact of electronic cigarettes on periodontal tissues and oral cancer initiation.

The second direction of research is an analysis regarding the optimal technologies and materials used in order to realize prosthetic constructions with adequate mechanical properties, with longevity over and which will allow the morphological and functional rehabilitation of the stomatognathic system.

The third direction of research is focused on the characteristics of three categories of resins used to make removable prostheses within analog and digital technologies (subtractive and additive methods). These materials were analyzed comparatively from the point of view of mechanical behavior. The conclusions of the study aim to guide specialists in choosing the optimal prosthetic solution, that leads to clinical results with great longevity over time.

In the fourth chapter entitled "Possibilities and limits of cross-infection control in the dental laboratory" I followed three directions of research, preceded by an update of the latest information in the literature on this extremely current issue.

The first direction of research is represented by researches on the knowledge and implementation of measures to control cross-infection in the dental laboratory. In order to conduct a study on the sources of contamination and the possibility of eliminating the risk of cross-infection, I analyzed the extent to which the notions of cross-infection prophylaxis are known and applied by dental technicians; the results and conclusions subsequently guide us to the other directions of research.

The second research direction approached the analysis of the concentration of powders and the degree of their microbial contamination in the dental laboratory, as a result of the different stages of prostheses processing

The third direction of research aims to analyze the possibilities of microbial contamination ofremovable prostheses after processing, depending on the tools and pastes used for finishing.

Section C presents future research directions, both scientifically and academically. In this sense, on the one hand, I want to continue the topic already addressed, specific to the discipline of Prosthesis Technology, and on the other hand, I want to approach new, innovative directions that allow interdisciplinary research in national and international teams.

The analysis of the characteristics of the materials and technologies for the realization of dental prostheses will remain an important concern in the future, aiming at consolidating the existing research core, expanding interdisciplinary collaborations, creating a high-performance research center for digital technologies and creating a defectoscopy center.

In this section I have highlighted the strategies and projects on the activity with future PhD students, detailing the research topics that can be addressed by them, namely: experimental research on fatigue and wear resistance of resins enriched with silver nanoparticles, methods of application and preparation of silver nanoparticles for resin optimization and microbial adhesion to the bases of prostheses made of resins optimized with silver nanoparticles; in vitro studies are useful for initiating clinical research on the analysis of changes in the external surface and color of acrylic full dentures nanoparticles enriched, as well as research on the possibilities of reducing inflammation of the oral mucosa to full dentures wearers.

Other research directions that will be developed are represented by comparative studies on digital and conventional technologies for the realization of complete prostheses and research on the possibilities of using digital technologies in the different laboratory stages.

Section D includes a list of the main reference works that have been consulted in order to elaborate the habilitation thesis.

Rezumat

Teza de abilitare, care rezumă activitatea mea profesională, academică și științifică, postdoctorală este încadrată în trei mari secțiuni, conform recomandărilor CNATDCU: Secțiunea I – Realizări științifice din perioada post-doctorală; Secțiunea II – Planuri viitoare în activitatea profesională, academică și științifică; Secțiunea III – Referințe bibliografice.

Lucrarea intitulată „Technological perspectives on the possibilities and limits of prosthetic treatment” reflectă preocupările mele de cercetare în domeniul tehnologiilor și materialelor de realizare a protezelor mobile, precum si interesul privind posibilitățile de optimizare a parametrilor biomecanici ai acestor.

In secțiunea A am realizat o scurtă prezentare a realizărilor profesionale, academice şi ştiinţifice din întreaga mea carieră didactică, începută în anul 1994.

După terminarea studiilor doctorale, mi-am continuat cercetările, lărgindu-mi aria de interes asupra altor tipuri de construcții protetice și am schițat astfel direcțiile de studiu ulterioare, pe care m-am concentrat din 2005 până în prezent: posibilități de optimizare a

proprietăților biomecanice ale incrustațiilor intratisulare, optimizarea structurii și calității materialelor utilizate în realizarea lucrărilor protetice fixe, posibilități de optimizare a caracteristicilor protezelor acrilice mobile, aspectele economice în practica medicinei dentare, posibilități și limite de control al infecțiilor încrucișate.

Teza de abilitare sumează cercetările asupra creşterii performanţelor rășinilor acrilice utilizate în realizarea protezelor mobile și optimizarea activității în laboratorul de tehnică dentară.

Secțiunea B sistematizează cercetările ştiinţifice postdoctorale asupra cărora m-am concentrat în cei 16 ani de activitate didactică și academică și este structurată pe trei domenii de cercetare. Această secţiune a tezei cuprinde cele mai relevante articole din activitatea mea științifică, indexate în Web of Science Core Collection și în baze de date internaţionale.

Primul capitol al acestei secţiuni, intitulat „Research on the characteristics and biomechanical behavior of acrylic resins for full dentures”cuprinde cercetări specifice domeniului Tehnologiei Protezelor şi Materialelor dentare, fiind precedat de o secţiune introductivă, care detaliază cele mai noi și relevante informaţii din literatura de specialitate cu privire la aceste teme.

Prima direcţie de cercetare este reprezentată de cercetări asupra caracteristicilor si comportamentului biomecanic al rășinilor acrilice utilizate pentru realizarea protezelor mobile totale, urmărind comportamentul acestor materiale, după introducerea în structural lor a nanoparticulelor de argint, în scopul prevenirii stomatopatiilor paraprotetice.

A doua direcţie de cercetare analizeaza efectul încorporării nanoparticulelor de argint asupra structurii și suprafeței rășinilor acrilice; cunoscând faptul că structura și calitatea suprafeței unei construcții protetice influențează adaptarea și longevitatea protezelor mobile, studiile realizate și-au propus să analizeze dacă introducerea nanoparticulelor de argint, procedeu foarte agreat de practicieni, modifică semnificativ structura și, implicit, comportamentul în timp al rășinilor acrilice

Cea de a treia direcţie a tezei s-a axat pe analizarea caracteristicilor suprafețelor rășinilor acrilice convenționale, autopolimerizabile și termopolimerizabile, în functie de tehnica de finisare și lustruire. Cocluziile studiilor oferă soluții practice tehnicienilor dentari, ghidându-i în alegerea metodei și instrumentarului optim de prelucrare, coroborate cu tipul de rășină utilizat.

Cel de **al doilea capitol** intitulat "Technological possibilities for full dentures realization" este, de asemenea, precedat de o secțiune introductivă care prezintă metodele convenționale și moderne de realizare a protezelor totale, precum și avantajele și dezavantajele materialelor utilizate în tehnologiile de realizare a acestor construcţii protetice, longevitatea acestor proteze și posibilitățile de refacere corectă a funcţiilor aparatului dento-maxilar

Prima direcţie de cercetare este reprezentată de studii privind principalele tehnologii utilizate pentru realizarea protezele totale, analizând care sunt metodele mai frecvent utilizate în practică pentru realizarea acestor lucrări protetice.

A doua direcţie de cercetare este reprezentată de o analiză a parametrilor mecanici ai protezelor acrilice realizate prin diferite tehnologii de polimerizare. Mecanismul de polimerizare influențează caracteristicile mecanice și comportamentul biologic al rășinilor acrilice, iar cercetările noastre au permis sistematizarea condiţiilor optime de polimerizare, pentru a obține lucrări protetice mobile cu parametri biomecanici optimi.

A treia direcţie se intitulează „Students' attitude regarding the implementation of digital technologies in current dental practice”.

Toate restaurările protetice moderne au o mulțime de avantaje, dar există și o serie de dezavantaje, care trebuie cunoscute, în vederea alegerii unei soluții terapeutice corectă.

În acest scop, studiile s-au concentrat pe analiza opiniilor studenților de la Specializarea Tehnică dentară, cu privire la implementarea tehnologiilor digitale în activitatea de laborator, precum și impactul pe care aceste metode l-ar putea avea asupra activității practice curente.

In cel de **al treilea capitol** intitulat ″The importance of clinical evaluation and materials used in prosthetic treatment" am analizat importanța factorilor locali și loco-regionali în alegerea solutiei terapeutice, precum si impactul design-ului și al materialelor utilizate pentru realizarea construcțiilor protetice asupra statusului oral.

Prima direcție de cercetare s-a concentrat asupra posibilităților de echilibrare orală în vederea protezării a pacienților cu diabet de tip II și la femeile aflate în perioada de post menopauză de asemenea, au fost analizate modificările la nivelul cavității orale determinate de fumat, urmarind în special pacienții care utilizează tigările electronice.

A doua direcție de cercetare este o analiză privind tehnologiile și materialele optime utilizate în vederea realizării unor construcții protetice adecvate din punct de vedere mecanic, cu longevitate mare în timp și care să permită refacerea în condiții optime a morfologiei și funcțiilor sistemului stomatognat.

In cea de a treia direcție de cercetare au fost analizate comparativ caracteristicile a teri categorii de rășini utilizate pentru realizarea protezelor convenționale și prin metode digitale substractive și aditive. Concluziile studiului își propun să ghideze specialiștii în vederea alegerii soluției protetice optime, alegând o tehnologie rapidă, care să conducă la rezulștate clinice cu longevitate mare în timp.

În al patrulea capitol intitulat " Possibilities and limits of cross-infection control in the dental laboratory" am urmărit trei direcții de cercetare, precedate de o aducere la zi a ultimelor informații din literatura de specialitate referitoare la aceasta problematică extrem de actuală.

Prima direcție de cercetare este reprezentată de cercetări privind cunoașterea și implementarea măsurilor de control a infecției încrucișate în laboratorul dentar. In vederea realizării unui studiu privind sursele de contaminare și posiblitatea eliminării riscului infecției încrucișate, am analizat măsura in care noțiunile profilactice sunt cunoscute și aplicate de către tehnicienii dentari; rezultatele și concluziile obținute m-au ghidat ulterior spre celelalte direcții de cercetare.

A doua direcție de cercetare a abordat analizarea concentrației de pulberi nocive și gradul de contaminarea microbiană a acestora în laboratorul de tehică dentară, rezultate ca urmare a diferitelor etape de prelucrare a protezelor.

Cea de a treia direcție de cercetare vizează analizarea posibilităților de contaminare microbiană a protezelor mobile după prelucrare, în funcție de instrumentarul și pastele folosite pentru finisare..

Secţiunea C prezintă direcţiile viitoare de cercetare, atât din punct de vedere ştiinţific, cât şi academic. În acest sens mi-am propus, pe de o parte, continuarea tematicii deja abordate, specifice disciplinei Tehnologia Protezelor Dentare și, pe de altă parte, doresc să abordez direcţii noi, inovatoare, care să permită cercetări interdisciplinare în cadrul unor proiecte naţionale şi internaţionale.

Analizarea caracteristicilor materialelor si tehnologiilor de realizare a protezelor dentare va ramane o preocupare importantă și în viitor, urmărind consolidarea nucleului de cercetare existent, extinderea colaborărilor interdisciplinare, crearea unui centru performant de cercetare pentru tehnologii digitale și crearea unui centru de defectoscopie.

În această secțiune am subliniat strategiile și proiectele privind activitatea cu viitorii doctoranzi, detaliind temele de cercetare care pot fi abordate de către aceștia, și anume: cercetări experimentale privind rezistența la oboseală și uzură a rășinilor îmbogățite cu nanoparticule de argint, metodele de aplicare și preparare a nanoparticulelor de argint destinate optimizarii rășinilor și aderența microbiană la bazele protezelor realizate din rășini optimizate cu nanoparticule de argint; studiile in vitro sunt utile pentru inițierea unor cercetări clinice privind analizarea modificarilor suprafeței extene și a culorii protezelor totale din rășini acrilice optimizate cu nanoparticule, precum și cercetări privind posibilitățile de reducere a inflamațiilor mucoasei orale la purtătorii de protezele totale din aceste materiale.

Alte direcții de cercetare care vor fi dezvoltate sunt reprezentate de studii comparative privind tehnologiile digitale și convenționale de realizare a protezelor mobile totale și cercetări asupra posibilităților de utilizare a tehnologiilor digitale în diferitele etape de laborator.

Secţiunea D include o listă a principalelor lucrări de referinţă care au fost consultate în vederea elaborării tezei de abilitare

SECTION A

OVERVIEW OF ACADEMIC, PROFESSIONAL, AND SCIENTIFIC ACHIEVEMENTS

Teaching is one of the most challengind ansd demanding profession because training the future doctors implies a huge responsibility, because it does not involve from the teachers only the transmission of some necessary knowledge in the future activity but also the formation of slightly strong characters. In this sense, there is a continuous concern for increasing the quality of the didactic process, paying special attention to the theoretical and practical activity, the active involvement of the students in the didactic act and in the research projects of the faculty.

In the 27 years of my university career, my professional training and improvement has been continuous, in order to optimize and permanently upgrade the teaching act.

At the same time, the sustained research activity that I carried out in these years allowed me to be permanently connected to the latest news in the field of dentistry. The results of the research within the discipline, but also within the interdisciplinary projects were useful in the educational process, the students being always up to date with the latest news regarding the materials and technologies used in dental technology.

As in other fields of medicine, huge advances have been made in dentistry, which have permanently changed the protocols and methods of treatment. In the discipline of dental prosthesis technology, we always connect the teaching activity with the research activity, in order to guide the students in the discerning choice of the optimal therapeutic solutions.

I have structured the presentation of my academic career according to the following plan: professional and academic activity, scientific research activity, achievements in the scientific publication area, clinical activity, recognition of the national and international level.

1. Professional and academic activity

My academic and scientific formation was carried out at Faculty of Dentistry, University of Medicine and Pharmacy „Grigore T Popa" Iasi, which I graduated in 1993, with doctor's degree, with the diploma series L nr.1184/27.IX.1993.

In 1994 I became junior assistant at Technology of Dental Prostheses discipline, Dental Medicine Faculty (249/1.04.1994).

I continued my didactic activity as Assistant Professor untill 1998 and in 2002 I became Lecturer at the same Department (14.718/14.10.2002).

Since 2017 until present I am Associate Professor at the Technology of Dental Prosthesis Discipline, Implantology, Removable Prosthesis, Technology Department, Faculty of Dental Medicine, „Grigore T Popa" University of Medicine and Pharmacy, Iasi.

I performed my teaching activity with students from the Dental Technician Specialization, namely with the 1-st year (Morphology of teeth and dental arches), 2-nd year (Technology of metal-ceramic bridges), 3-rd year (Technology of full denture), Dental Medicine Specialization - Romanian Section, with the 1-st year (Morphology of teeth and dental arches) and 4-th year (Technology of full denture) and from 2010 with the students of Dental Medicine Specializatin - French Section with the 1-st year (Morphology of teeth and dental arches), 3-rd year (Technology of dental crowns), 4-th year (Technology of full dentures) and 5-th year (Technology of removable partial dentures).

Throughout this period, I focused my concerns on the permanent reorganization of the teaching process, by restructuring the content of the syllabus and curricula, following their connection to the norms imposed by the european community. I have always followed that theoretical and practical training of graduates must be related to the needs and requirements of the national and international labor market

Dental technology is a field in a permanent dynamic, and the materials used in dental prosthetics have evolved enormously in recent years, practically revolutionizing dentistry. In this context, both the students from the Dental Technique specialization and the ones from Dental Medicine must be connected to the novelties in the field. Therefore, during the scientific debate meetings that take place within the discipline of Dental Technology, new methods of prosthetic treatment were presented and discussed, stimulating training specialists to know new technologies and compare them with conventional methods. Also, involving the students in making these presentations of the clinical and technological steps of making different types of prostheses, we aimed to increase their appetite for research. By training them in this sense and teaching them to corroborate the activity of learning and accumulating new information with the research activity, we prepared them for the final stage, of accomplishing the bachelor's thesis. In my teaching activity I guided, on average, a number of 15 bachelor's theses per year, in the specialization of Dental Technique and in the specialization of Dental Medicine, works that brought to attention new technologies and prosthetic therapeutic solutions for complex clinical cases.

The pandemic with SARS-CoV-2 was a new challenge in everyone's activity, which forced us to restructure the learning process, without the didactic act being affected from the qualitative point of view.

In this situation it was necessary to rethink the teaching methods, to design plans, reports and presentations, according to this new way of working.The students benefited from all the necessary materials, the practical works were filmed and distributed to them, so that, thanks to the electronic platforms, they continued their training process, without major difficulties. Along with the mandatory disciplines, we followed the introduction in the educational process of some optional disciplines, which would allow the students to capitalize on other values, indispensable to the specialists in the field of medicine.

Thus, in the specialization Dentistry, for the first year, the French language series I introduced the optional course „Éléments de la morphologie fonctionnelle des dents et des arcades dentaires", which offers students the opportunity to deepen the notions of morphology and to correlate the elements of dental anatomy with the functions of the dento-maxillary system.

Besides the didactic activity with the students from the bachelor program, I am also involved in the preparation of the master students, supporting courses and practical activities with the students within the master program „Modern techniques in aesthetics and technological rehabilitation in particular edentulous situations".

Also within the project financed by Agence Universitaire de la Francophonie (AUF)- L'assurance de la qualité dans l'enseignement superieur par la formation de specialistes dans le domain de la Rehabilitation Orale Complexe and carried out in the period 22.06-20.12.2020, I held online courses for French-speaking teachers in the member countries of the CIDCDF association and 6th year students, French language series, Faculty of Dentistry.Another activity in the didactic area is represented by the training of residents in the General Dentistry specialization. Within this program I support courses and practical works for second year residents.

2. Scientific research activity

I have been admitted to be PhD training at the 'Grigore T. Popa' University of Medicine and Pharmacy Iaşi, Faculty of Dental Medicine in 1999 and I publicly supported the work in 2004. I was awarded the title of Doctor in Dental Medicine in 2005, (Doctor's Degree Series D no. 0002875, Order of the Minister of Education and Research nr. 3956/ 25.IV.2005) – with the thesis „Consideration about indirect inlay restorations" (Scientific coordinator Prof.univ.dr. Ştefan Lăcătuşu).

My doctoral thesis was divided into two sections: stage of knowledge and personal contribution.

In the first part I focused my research on comparing the biomechanical properties of the materials used in inlay systems, classic and modern technologies used for inlay systems and on the possibilities of optimizing the biomecanical properties of the inlays.

In the second part, represented by personal research, I followed several particular aspects regarding the characteristics of these prosthetic restorations:

-Long therm survival estimates of cast gold and aesthetic inlays- a clinical comparison at five years,

-Technical posibilities for improving the structure of metalic inlays,

- Aspects of the biomecanical behavior in inlay restorations,

- Study regarding the influence of the tensions induced by the restorative material on the dental tissues.

The originality of my doctoral thesis consisted in this comparative analysis between the three major categories of materials used in making inlays, these prosthetic restorations so precise and difficult to achieve from a technological point of view. At the time the doctoral research was conducted, there were few comparative studies in this regard, and opinions on the characteristics, advantages and disadvantages of the materials were divided and contradictory.

The research I carried out, using the Finite Element Method, then completed by mechanical tests, carried out in collaboration with the Faculty of Materials Science and Engineering- Technical University „Gheorghe Asachi” Iași, allowed us to concretize some pertinent conclusions, with important practical impac.; thus, we were able to systematize which are the optimal materials for making the inlays restorations, depending on the amplitude of the dental destruction and the position of the tooth on the dental arch.

After finishing my doctoral studies, I continued my research, in the direction of optimization the mechanical properties of inlay prosthetic constructions. The digital technologies that have appeared in the meantime require the use of new materials that need to be analyzed; also the marginal adaptation, at the level of the interface, is another important aspect that must be followed. In this sense, we wanted to comparatively analyze thismarginal area to inlays made by conventional methods and digital methods.

Subsequently, the area of interest in my research activity extended to other types of prosthetic constructions and thus defined the subsequent study directions, which I have focused on from 2005 until now.

In the field of fixed prostheses, the research activity focused on two main directions:

-optimizing the structure and quality of materials used in fixed prosthetic works

-clinical and experimental studies relating to the primary and secondary prevention in case of dental treatments using dental materials and alloys;

Another area of great interest for me is the analysis of the possibilities and limits of cross-infection control in the dental laboratory. In this sense, my studies were aimed at detecting the main sources of contamination in the dental laboratory, establishing measures to reduce the risk of contamination and the implementation and systematization of these measures in a guide of prophylactic measures to protect patients and members of the dental team, to allow the reduction of the number of pathogenic germs in the workspace and to ensure the implementation of a high standard in the control of cross-infection.

Another important research direction on which I focused my attention was the possibility of optimizing the characteristics of acrylic mobile prostheses. In aceasta directie am analizat principalele tipuri de rasini acrilice utilizate in laboratul de tehnica dentara in vederea realizarii protezelor mobile, urmarindu-le parametrii mecanici, starea de suprafata si longevitatea in timp, cautand sa optimizez proprietatile acestora si sa crec performantele biologice si functionale. A relevant study conducted during this period was to analyze the bio-mechanical performance of dental acrylic resins silver nanoparticles enriched.To provide antibacterial properties, in the last years more attention has directed toward the incorporation of silver nanoparticles into acrylic resins. Silver particles utilization aims to avoid or at least to decrease the microbial colonization over dental materials, increasing oral health status and improving life quality. A question still remains: how AgNps could influence the structure, mechanical and physical properties of the resins.

In our researches we investigate the stress distribution in a dental acrylic resins reinforced with silver nanoparticles with different diameters and in different concentrations. Our conclusions have great clinical importance and determine the optimal size and concentration so that the nanoparticles do not affect the mechanical characteristics of acrylic prostheses.

In addition to research directions in the field of technology and dental materials, I have conducted studies and research on the dental students attitude toward patients with chronic diseases, on the importance of knowing the ethical aspects in dental practice and on the economic aspects of oral health (the influence of economic crisis on the management of dental office and dental technique labs). During these researches we followed the knowledge of bioethics and deontology for students of Dental Medicine and Dental Technique Specialisation, and how these notions are applied, in relation to patients with a special pathology. The conclusions of these researches focused us on the directions that need to be improved and on the aspects that need to be emphasized in the training of future specialists in dentistry..

Also, as a result of the extension of digital technologies in the current laboratory practice, it was analyzed the point of view of the students from the Dental Technician Specialization, but the opinion of dental technicians practitioners was also followed, regarding the impact that these new methods will have on their future activity. In this sense, we made several sets of questionnaires, which we distributed to a large number of students and specialists in dentistry; Following the analysis of their answers, we were able to systematize a series of pertinent conclusions, which will guide us in the process of training future specialists.

The most recent field of interest in the research activity is represented by the impact of digital technologies on dental activity during the SARS Cov 19 pandemic. The present study aims to analyze the impact that these modern methods of treatment have on the current activity of dentists and how digital technologies have influenced the addressability of patients in dental offices during the pandemic. In this sense, we realized a questionnaire that was distributed to a number of 114 dentists with private practice in Iasi.

The answers clearly show that dentists want to implement digital systems in current dental practice, which would allow prosthetic work to be performed in a shorter time and with maximum accuracy, reducing working time and materials, reducing the risk of contamination, both for patients as well as for the dental team. Minimizing treatment time and the number of appointments is not only favorable for the patient, but also excludes complications and it is possible to obtain optimal treatment results by simplifying the entire procedure

My participation in several projects allowed me to materialize these different directions of research, both within the discipline and in collaboration with other disciplines and faculties.

In 2015 I was research grant director of the project „Effect of silver nano-particles on the properties of acrylic dental resins" No. 31588 / 23.12.2015. 2015-2017, in which we analyzed the structural changes, mechanical properties and behavior over time of different types of resins enriched with nanoparticles, frequently used in the laboratory for the realization of prosthetic constructions.

In 2018 I was a member of a complex project carried out in a CDI consortium: "Obtaining and expertise of new biocompatible materials for medical applications, no. 63 / 19.03.2018, (MedicalMetMat), type grant PN III – PCCDI, project director Forna Norina Consuela. The project aimed at an extensive analysis of new alloys that can be introduced in current dental practice, in order to create prosthetic devices, metallic or on metallic structure.

The results of our research constituted important information for practitioners, who were thus able to widen their range of therapeutic options and choose with much discernment the optimal therapeutic solution, knowing in detail the advantages and disadvantages of the materials used.

In addition to the research activity in the field of biomaterials, I was also a member of various educational projects, with an impact on the teaching and research activities. I participated as a member in the group of experts within the Project "Practical training courses for the rapid integration on the labor market of students specialized in dentistry", Contract number POSDRU / 90 / 2.1 / S / 63942, 2007-2013, Project Director Prof.univ .dr. Norina Forna, member in the project Prevention of school dropout and counseling in choosing the career path for first year students of Dentistry and Dental Technique (Be.MeDTech), member of the target group Quality Assurance Commission within the project “Adapting the offer of higher dental medical education to the needs of the labor market and of the knowledge-based society” POSDRU / 86 / 1.2 / S / 63699, 1.07 2010-30.06.2013, Director poiect Prof .univ.dr. Norina Forna; I was also a member of the target group of the MEDICALIS project-Educational Management and Quality Education in the Information Society ”, Contract number POSDRU 86 / 1.2 / S / 62594, 1.07.2010-30.06.2013, Project Director Prof.univ.dr. Norina Forna, member in the project "Insertion of medical graduates on the labor market, through the development of internships in practical training of practical skills-MEDPRO, and member in the project financed by Agence Universitaire de la Francophonie (AUF)-L'assurance de la qualité dans l'enseignement superieur par la formation de specialistes dans le domain de la Rehabilitation Orale Complexe, 22.06-20.12.2020.

Starting with 2020, I was a practical skills mentor within the project Insertion of medical graduates on the labor market, through the development of practical skills training courses - MEDPRO, 2.11.2020-21.09.2022, and in 2022 I participated as student training expert within the project "Quality in education through knowledge of deontology, ethics and gender discrimination in the academic environment-CEMED 2022".

The results of these studies have been translated into a number of articles published in extenso in Web of sciene Core Collection-indexed journal with impact factor, in ISI proceedings volumes, in International database listed papers in articles published in extenso in the volumes of international conferences and in oral presentation at national and international congresses.

3. Achievements in the scientific publication area

My research activity was mostly focused on analyzing the technologies and materials used for the realization of prosthetic constructions, considering that the discipline in which he has been working for 30 years - Dental Technology - is closely related to the specialization of Dental Prosthetics.To create an artificial substitute, several laboratory steps are necessary, and knowing the particularities of each method and the characteristics of each material used is of great importance. The success of a prosthetic treatment is influenced to a great extent by the technology chosen; that's why, in the research I've done, I've focused on the possibilities of optimizing the materials used for prostheses realization through conventional methods and analyzing the characteristics of materials and systems that have recently appeared on the market.

The research results were intended to be useful in practice and to provide clinicians with useful information so that they can choose the optimal therapeutic solution for each individual clinical case. My professional experience was used in the development of manuals, books and book chapters:

1. **Diana Antonela Diaconu**, Monica Silvia Tatarciuc, - Éleméments de morphologie de l'appareil dento-maxillaire, Editura Pim, Iași 2021, ISBN 978-606-13-56152-6
2. Monica Silvia Tatarciuc, **Diana Antonela Diaconu**, Diana Tatarciuc- Elemente de morfologie a sistemului stomatognat, Editura Pim, Iași 2020, ISBN 978-606-13-5468-9

3. **Diana Diaconu-Popa**, Monica Silvia Tatarciuc, Anca Vițalariu-Technologie de la prothese totale, Ed. Performantica Iaşi 2019, ISBN 978-606-685-661-4
4.**Diana Antonela Diaconu,** Monica Silvia Tatarciuc, Technologies des protheses unidentaires- Ed Performantica Iasi, 2012, 180 pg., ISBN 978-973-730-948-8
5. **Diana Antonela Diaconu**, Monica Silvia Tatarciuc, Particularitati tehnologice in realizarea puntilor ceramice, Ed Performantica Iasi 2015, 313 pg, ISBN 978-606-685-241-8
6.**Diana Antonela Diaconu,** Monica Silvia Tatarciuc, Tehnologia Protezelor mixte metalo-ceramice, Ed.Junimea, Iași, 2006, ISBN(13) 978-973-37-1216-9
7.**Diana Diaconu,** Monica Tatarciuc, Anca Vitalariu, Prevenirea afecțiunilor stomatologice, Capitol IV- Prevenirea afectării stării de sănătate generală în medicina dentară-Posibilități și mijloace de prevenire a infecției încrucișate în laboratorul de tehnică dentară- Ed. „Gr.T.Popa" UMF Iași, 2014, ISBN 978-606-544-229-0
8.Anca Vitalariu, **Diana Diaconu**, Irina Chonta, Monica Tatarciuc-, Gutierele pentru protecție în activitățile sportive, Cap.IV.7., p.259-273 , Vol. Managementul preventiv și interceptiv al afecțiunilor stomatologice la copii și adultul tânăr, ISBN 978-606-544-392-1, 2016
9.Anca Vitalariu, Cristina Masgras, Irina Chonta, **Diana Diaconu-Popa,** Monica Tatarciuc- Impactul local şi sistemic al refacerii morfologiei ocluzale şi a funcţiei masticatorii, Cap.II.15, p.163-173, Vol. Sănătatea orală în contextul sănătăţii generale, 2017
10. Monica Tatarciuc, **Diana Diaconu-Popa**, Anca Vitalariu-Prevenirea afecţiunilor orale determinate de coroziunea aliajelor dentare, Cap.III.11, p.266-273, Vol. Sănătatea orală în contextul sănătăţii generale, 2017

The results of the research materialized in articles published in extenso in ISI Web of Science Core Collection -indexed journals, 25 as main author and 7 as co-author in ISI listed papers, 50 articles as main author and 6 as co-author in international databases listed papers. Also, in order to disseminate the conclusions of the studies, I participated in scientific congresses with over 100 oral presentations.

The interest in the research carried out was expressed in a number of 95 citations in ISI Web of Knowledge-indexed journals and a Hirsch Index (Clarivate Analytics) 7

4. Clinical activity

My concern for my training as a dentist was continuous, the professional trajectory following thebegins as trainee doctor during January-March 1994, at the Dental Gnatoprosthetics Clinic of the University Clinic no.1 Iaşi, continued as resident doctor confirmed with the order of M.S.nr.2017 / 1994, March 1994-November 1996 at the University Clinic no.1 Iaşi and finally as specialist doctor 1996-2001 general dentistry, confirmed by order of M.S. nr.2707 / 18.XII.1996

In 2001 I became a senior dentist, specialty of general dentistry, confirmed with the order of the Ministry of Health no..538/07.08.2001; I am also a specialist doctor in the second specialty - Dental Prosthetics and in 2012 I was confirmed as a senior dentist in the second specialty Dental Prosthetics, order of M.S. no. 1077 / 2012.

In all these years, I continued developing my professional education, by involving in post-graduate training courses, scientific and research-related projects. I have participated at various international and national courses with international participation, national courses and conferences.

The most relevant courses are: Courses of the Pedagogical Seminar, within the University „AL.I.Cuza" Iaşi, 1995-1996, „Actualities in periodontology, endodontics and cariology", 1-31.03.1997, UMF Iaşi, International Seminar on Dentistry „Rehabilitation Orale Complexe", 18-20 mai 1998, Dental treatment for general health compromised patients" (Prof. Dr. Adi Garfunkel – Israel), 27-31 mai 1999, Iaşi, „The surgical treatment in parodontopathies" (Prof. Dr. Wember Matthes – Germania), 14-17 iunie 1999 Iaşi, International postgraduate course in Periodontology (Prof.Dr. W.Matthes – Germania), 29.11-4.12.1999, Iaşi, International postgraduate course in hypnosis in dentistry (Prof. Dr. Vlad Solomon – Israel), 29.11-4.12.1999, Iaşi, „Actualities in contemporary dentistry", May 18 - June 16, 2001, Iaşi, „Biointegration of oral implants", Congress "Drugs, biomaterials, equipment and techniques in dentistry", 27.02-1.03 2002, Iaşi, „Flexite elastic thermoplastic materials. R-3C injector "(Szalina Luis Albert - dental technician), organized by the Faculty of Dentistry UMF Iaşi and Nastimed-Cluj Napoca), December 2005, Iaşi, "Periodontal incidents of fixed prosthetic treatments" (Prof. Dr. Teodor Traistaru Oct.2006, Bucharest, „ Prophylactic and treatment applications from the perspective of specifying the diagnosis in gingivo-periodontal diseases" (Prof. Dr. Horia Dimitriu), oct. 2006, Bucharest , „ Cast removable parial denture with clasps - logical concept, efficiently practicable everywhere" (Prof.Dr. Ion Coca/ Germania), oct. 2006, Bucharest, Continuing medical education courses credited during the EURODENTIS 1 congress, on the occasion of the 10th anniversary of AMS Iaşi, March 2007, postgraduate course "Smile Aesthetics" (Dr. Elliot Mechanic / Canada) - Marriot Grand Hotel, Bucharest, April 13, 2007, „Attachement and telescope retainers in the therapy of partial edentulism"(Prof. Dr. Forna Norina Consuela), Iaşi, March 20-21, 2008, postgraduate course "Actualities on the risk of medical emergencies in the dental office" (Prof. Dr. Forna Norina Consuela), Iasi, June 2007, postgraduate course "Principles of scientific medical writing", 15.06.-10.07.2009, UMF Iasi, postgraduate course „ Research ethics in Romania " 9-11.11.2009, UMF Iasi, „ postgraduate course Current approaches in implant-prosthetic rehabilitation "- Dental technician Richard Abulius (France) and Prof. Dr. Georges Khoury (France), 25-26 Oct.2010, Iasi, Romania (Lectures:": „Alternatives a la chirurgie reconstructrice des pertes tissulaires par les gencives artificielles" – R. Abulius; „Evolution des augmentations osseuses: des prelevements auto;ogues aux osteotomies segmentaires"), training courses for trainers in oral rehabilitation, 21.01-28.02.2013, UMF, Iaşi, Postgraduate course Medical and dental emergencies, April 14, 2016, Bucharest, postgraduate course Medical and dental emergencies, Iasi, 2017.

In the Dental Technology discipline' coordinate the activity of the dental laboratory, where the scale of prosthetic works for the disciplines of Fixed Prosthesis, Partial removable Prosthesis and Complete Removable Prosthesis is performed. Thus, my activity involves checking the quality of each prosthetic element within the technological algorithm, but also the standards of prostheses made in the laboratory. Also, our activity involves coordinating the activity of the laboratory and supervising the clinical and technological steps of performing fixed and mobile prosthetic restorations.

5. Recognition at the national and international level

I am currently member in two international scientific societies and 4fournational societies:

- European Prosthetic Association of Dental Public Health (EPA)
- Balkan Stomatological Society (BASS)
- Romanian Dental Association for Education (ADRE)
- Romanian Association of Oral Rehabilitation (ASRRO)

- Society of Physicians and Naturalists (SSM) Iasi Branch
- The College of Stomatologists from Romania (CMSR)-

In 2015 I received the UEFISCDI award for the research paper published in ISI journals located in the top area, within the HUMAN-RESOURCES-Program — Research projects to stimulate the establishment of young research teams, December 2014 session:
Diana Diaconu, Anca Vitalariu, Monica Tatarciuc, Alice Murariu, The economic crisis effects on the cross contamination control in dental laboratories, Revista de cercetare şi intervenţie socială, 2014, vol. 47, 105-117, PN-II-RU-PRECISI-2015-9-8471, position 1073

My scientific publlications have counted over 95 citations in ISI Clarivate Analytic Indexed Journal, and participation in international and national scientific events, with conferences or as a member of scientific committees have contributed to increasing the prestige of the discipline and to increasing the visibility of the Faculty of Dentistry.

SECTION B

SCIENTIFIC ACHIEVEMENTS FROM THE POSTDOCTORAL PERIOD

CHAPTER 1

RESEARCH ON THE CHARACTERISTICS AND BIOMECHANICAL BEHAVIOR OF ACRYLIC RESINS FOR FULL DENTURES

1. EFFECT OF SILVER NANOPARTICLES INCORPORATION ON MECHANICAL PARAMETERS OF DENTAL ACRYLIC RESINS

State of the art

Acrylic dental resins are commonly used in dentistry for different purposes such as partial and complete denture, epithesis, orthodontic functional appliances, anti-snoring or bruxism mouth guard, due to their advantages: good physical properties, sufficient strength, low water sorption, low solubility (Raszewski et al., 2021, Hsu et al., 2020). However, a series of disadvantages have also been reported: poor mechanical properties, high coefficient of thermal expansion, low modulus of elasticity and mucosal irritation, caused by the release of methyl metacrylate or by the bacterial colonization. One of the major disadvantages of removable prostheses, frequently reported by practitioners, is their insufficient mechanical strength, in certain clinical situation (Allahyari et al., 2018, Bettencourt et al., 2010).

Over years, many attempts have been made to improve the mechanical properties of acrylic resins in three directions: the development of alternative materials. (Köroğlu et al., 2016) the chemical modification by the addition of various polymers (Machado-Santos et al, 2020, Morais et al., 2007) and the reinforcement of polymethyl methacrylate with other materials, such as carbon fibers, glass fibers, metal inserts (Elshereksi et al., 2017)

Another disadvantage that specialists faced is the mucosal irritation caused by microbial adhesion to inner denture surface. Epidemiological studies report that approximately 70% of removable denture wearers suffer from denture stomatitis, Candida albicans being regarded as essential prerequisites for denture stomatitis. The elderly patients with removable acrylic prosthesis present difficulties on keeping the denture clean. Recently, to induce antibacterial properties, more attention has been paid to the incorporation of silver nanoparticles (AgNps) into acrylic resins. AgNPs incorporation aims to avoid or at least to decrease the microbial colonization over dental materials, increasing oral health levels and improving life quality (Alla et al., 2020, Swamy et al., 2018).

Nanotechnology brings emerging changes in translational research in the last couple of decades. Nanomaterials have gained popularity for countless applications in various fields including clinical dentistry. In dentistry, nanotechnology has revolutionized the materials interaction and behaviour with oral structures such as antibacterial dental adhesive, nanoparticles based aesthetic restorative materials, surface decoration on dental implants, high strength denture bases (Zafar et al., 2017). Better understanding of materials and oral tissues interface at nanoscale has attracted many researches for therapeutic dental applications such as fluoride release, drug delivery. Silver (Ag) salts have been used for thousands of years, because of their antimicrobial efficiency against Gram-positive and Gram-negative bacteria, protozoa and fungi, as well as viruses. Nowadays, elemental Ag and associated compounds are used to reduce the risk of infection in the treatment of burns, prevent bacterial colonization on medical devices, in surgical textile fabrics, for water purification, bone cements, and dental materials. In dental applications, different forms of Ag such as Ag ions (Ag+), Ag nanoparticles (AgNPs), and Ag-polymeric complexes have been used to improve antibacterial efficiency. The instability of Ag+, however, restricts its practical implementation. The problem can be resolved by protecting the Ag+ with a polymeric matrix sheath. The major advantage of using AgNPs arises from their large ratio of surface area to volume. AgNPs exhibit more effective ion release and enhanced antimicrobial activity. AgNps have been satisfactorily incorporated into polymers used as tissue conditioners and as denture base.

The influence on the features of resins depends on the type of nanoparticles (size and shape), and concentration as well. AgNps have been added to resins due to their proved antimicrobial effects, but their influence on the mechanical properties is not completely elucidated. Even all researchers agree on the antibacterial effect of AgNps, the influence on the mechanical properties is still controversy. Some experts found that AgNPs incorporation within acrylic prosthesis material can improve its physical and mechanical properties, while there are also studies demonstrating negative effects on the resins features (Mathew et al., 2014, Soygun et al., 2013)

Their unique chemical and physical properties and pronounced antibacterial activity, provide one of the most cost effective antibacterial agents for applications in medicine for: diagnosis, treatment, dug delivery, bone cements, cardiovascular implants, medical device coating, wound dressings, medical textiles, contraceptive devices, etc. Induction of antimicrobial activity in dental materials has been widely a large concern in dentistry, their usefulness being proved in Orthodontic adhesives, Dental instruments, Endodontics filling materials and Prosthodontics. Despite the continuous progress in material science, Polymethyl Methacrylate (PMMA) is still the most used material for denture bases. A common problem faced by the acrylic denture wearers is the denture stomatitis, which is related to the specific conditions of the oral cavity, the state of the patient's immune system, but also to the PMMA surface characteristics, that facilitates the bacterial-fungal biofilm formation (Khanna et al., 2013, Zebarjad et al., 2011)

The classic treatment for denture stomatitis is based on topical or systemic antifungal drugs, but this infection is often persistent, since antifungal resistance has been reported in Candida Albicans biofilm. So, the prophylaxis of dental stomatitis by AgNPs incorporation represent a challenge.

The antimicrobial effect of AgNPs was demonstrated to be directly proportional to the concentration and inversely proportional to their diameter. Normally, a high concentration leads to more effective antimicrobial activity, while particles of small size can kill bacteria at a lower concentration. Particles larger than 100 nm showed only a bacteriostatic activity, while smaller particles have bactericidal effect. The smaller the particles (l< 10nm), the greater the antimicrobial effect (because they can penetrate into the bacteria, not only on it's surface).

The antimicrobial characteristic of AgNPs in acrylic resins has been demonstrated in a lot of studies (Oyar P et al, 2018; Dakal TC et al, 2018; Qayyum S et al, 2016) but there are few studies which analyzes the influence of NPs on the mechanical properties of denture base resins (de Souza Neto et al., 2019, Köroğlu et al., 2016, Monteiro et al., 2015, Zomorodian et al., 2011)

In addition to the undeniable advantage of antimicrobial action the addition of AgNPs effect on the mechanical properties of the resin should be examined with more attention.

The study of Sodagar (Sodagar JA et al, 2012) demonstrated that the addition of 0.05% AgNPs caused a decrease in the flexural strength of one brand of self-curing resin but led to an increase in the other brand's strength.

The type of acrylic resin and the amount of NPs incorporated are important factors which can affect the biomecnanical characteristics of PMMA. There are also studies that conclude that the incorporation of AgNPs optimizes the mechanical parameters of acrylic resins, especially flexural strength (Kassaee et al., 2008) indicated that adding.

So, regarding the influence of silver nanoparticles on the structure and properties of acrylic resins, the conclusions of the studies are controversial. Most of researchers agree that, in low concentrations AgNPs have no negative effects on the mechanical properties of acrylic resins.

Another important factor that influences the mechanical properties and clinical behavior of complete dentures is the porosity. Resins porosity is a complex, plurifactorial phenomenon and numerous studies have aimed to evaluate (qualitative and/or quantitative) the porosity of acrylic resins, a universally accepted standardization for pores size has not been imposed yet.

According to the ADA "there must be no bubbles or voids when viewed without magnification", pointing out that clinical highlighting is difficult. In the specialty literature the acrylic resins porosity is incriminated as factor favoring the denture stomatitis and fractures of dentures bases, due to their presence on the fracture line and on the interface artificial tooth / denture base.

The porosity is a non-desirable characteristic to the acrylic resin denture base (Figuerôa RMS et al. 2018) that can weaken the prosthesis and result in high internal stress, leading to greater vulnerability to distortion and warpage (Kasina et al., 2014) . A porous surface promotes colonization of the material by oral microorganisms such as Candida albicans (de Oliveira et al., 2010) and facilitates the retention of substances and deposition of calculus, resulting in staining and impaired aesthetic (Al-Fouzan et al, 2017, von Fraunhofer et al., 2009).

Regarding the porosity of acrylic resins, experimental studies results have been extremely variable, sizes falling between 10 and 300 μm, however, much higher values (500μm) being reported. Currently accepted and used classification distinguishes small pores (approx. 10 micrometers diameter), medium pores (10-30 μm diameter) and large pores (over 30 μm diameter).

Denture plaque formation occurs as a result of adhesion of various microorganisms to the acrylic surface of dentures. According to some in vivo studies clinically acceptable roughness (Ra) of hard surfaces in the oral environment after polishing should not exceed 0.2 μm.

Results of several studies have indicated that surface roughness of acrylic resin polished with prophylactic pastes, various rubber polishers, abrasive stones, and pumices still exceeds the threshold at Ra of 0.2 μm (Durán et al., 2020). The value reported as characteristic of smooth acrylic resin is 0.12μm. However, surface roughness of polished acrylic resin may vary between 0.03 and 0.75μm.

Dental technicians use effective techniques for polishing denture base acrylic resin, because the surface characteristics of acrylic resins vary according to the type of finishing and polishing systems. Some glazes have been used for sealing acrylic dentures. According to the manufacturers, a glaze would make the acrylic resin surface smoother, decreasing accumulation of residual food and plaque adhesion, and providing improved oral hygiene conditions.

Another important physical property of these dental materials is the wettability, affecting both bacterial colonization and denture retention in the oral cavity, therefore it is recommended to use materials with increased wettability for dentures base (Rao DC et al., 2015; Al-Kheraif AA et al., 2014).

Water absorbed by acrylic resins during the use of prosthesis acts as a plasticizer and can result in volume changes, so the water sorption evaluation also has clinical relevance. Furthermore, residual monomer and other water soluble byproducts are released into the oral cavity and may cause tissue irritation; therefore, it is desired that these materials have low solubility (Kasina SP et al, 2014; 94. Jin N-Y et al, 2009)

My contributions to this research direction can be found in the following articles:

1. **Diaconu-Popa D**, Viţalariu A, Tatarciuc M, Munteanu F. Effect of silver nanoparticles incorporation in dental resins on stress distribution- Finite Element Analysis. *Rev.chim. (Bucharest)* 2016; 67(8):1571-1574. **IF=1.232.**
2. **Diaconu-Popa D**, Comaneci R, Tatarciuc M, Murariu A,Vițalariu AM. Influence of silver nanoparticles on mechanical properties of dental acrylic resins *Rev.chim. (Bucharest*) 2016; 67(1): 2016:2311-2313. **IF=1.232.**
3. Vițalariu A, Tatarciuc M, Luca O, C Holban Cioloca C, Bulancea B, Aungurencei A, Aungurencei O, Raftu G, **Diaconu Popa D**. Structural and Thermal Changes in Dental Resins Enriched with Silver Nanoparticles. *Rev.chim. (Bucharest*) 2019; 70(2):591-595. **IF=1.755.**
4. Viţalariu AM, Lazăr L, Buruiană T, **Diaconu D,** Tatarciuc MS. Studiu privind starea de suprafaţă a răşinilor acrilice in raport cu metodele de prelucrare mecanică. *Rev Med Chir Soc Med Nat Iasi* 2011; 115(2):542-547.
5. Viţalariu AM, **Diaconu D**, Tatarciuc D, Tatarciuc MS. Factori implicaţi în colonizarea microbiană a răşinilor acrilice. Re*v Med Chir Soc Med Nat Iasi* 2012; 116(2):600-604.

Introductions

To provide antibacterial properties, in the last years more attention has directed toward the incorporation of AgNps into polymers used as tissue conditioners and as denture base.

The prophylaxis of dental stomatitis still represents a challenge for dentists and more studies are necessary in order to find the optimal prevention method. Silver particles utilization aims to avoid or at least to decrease the microbial colonization over dental materials, increasing oral health status and improving life quality. The question is if AgNps could influence the structure, mechanical and physical properties of the acrylic resins.

In our researches we investigate the stress distribution in a dental acrylic resins reinforced with with different diameters and different concentrations

In order to predict the optimum size and distribution of AgNps as average distance between particles, a finite element analysis (FEA) was performed, revealing the stress field at the particle/matrix interface.

In dentistry, Finite Element Analysis has been used to simulate different dental structures and internal stresses in teeth and dental materials. Because of the large inherent variations in biological material properties and anatomy, mechanical testing involving biomaterials usually require a large number of samples.

FEA-based studies are indicative only, so our research has also focused on the effects of AgNPs on the mechanical properties dental acrylic resins; we also followed up on any structural and thermal behavior changes of the composite material AgNPs modified.

The results of studies on the effect of silver nanoparticles incorporation on mechanical parameters of dental acrylic resins are illustrated by the following publications:

1.**Diaconu-Popa D,** Viţalariu A, Tatarciuc M, Munteanu F. Effect of silver nanoparticles incorporation in dental resins on stress distribution- Finite Element Analysis. *Rev.chim. (Bucharest)* 2016; 67(8):1571-1574..
2. **Diaconu-Popa D**, Comaneci R, Tatarciuc M, Murariu A, Vițalariu AM. Influence of silver nanoparticles on mechanical properties of dental acrylic resins *Rev.chim. (Buchare*st) 2016; 67(1): 2016:2311-2313.
3.Vitalariu A, Tatarciuc M, Luca O, Holban Cioloca C, Bulancea B, Aungurencei A, Aungurencei O, Raftu G, **Diaconu Popa D**. Structural and Thermal Changes in Dental Resins Enriched with Silver Nanoparticles. *Rev.chim.(Bucharest)* 2019; 70(2) 591-595.

Materials and methods

In order to track the influence of silver nanoparticles on the specific properties of acrylic resin it was first made a virtual model to perform a finite element analysis; then it was realized samples of acrylic resins, which have been subjected to mechanical testing.

In dentistry, Finite Element Analysis has been used to simulate different dental structures and internal stresses in teeth and dental materials. Because of the large inherent variations in biological material properties and anatomy, mechanical testing involving biomaterials usually require a large number of samples this method is extremely useful to create a guideline for future in vitro tests.

To determine the tensions within a composite material consisting of silver nanoparticles and acrylic resin a FEM analyze was performed, using Autodesk soft (Autodesk AutoCAD 2014 and Autodesk Simulation Mechanical 2014).

Designing the geometry of the resin is a complex procedure that requires a higher accuracy. In order to create the mathematical model it should be understood the physical behaviors of the composite material, predicted the performance and the behaviour of the design and identified the optimal concentration.

The Finite Element Method is a computational technique which is dividing a model body into an equivalent system of many smaller units (finite elements) interconnected at nodal points.

For the analysis we considered two hypotheses: assumptions related to the mechanical solicitation of the material and assumptions concerning the type of the tested material. For this study, silver nanoparticles with dimensions of 20 nm, 40 nm and 60 nm are used, and for each dimension, three different concentrations of 5%, 10%, and 20% are taken into account.

The construction of the geometric model consisted in making a cube of acrylic resin inside which the nanoparticles will be located. These constructive units were arranged as follows: four in length, three in width and four in height, so that in the final volume there will be 48 nanoparticles for each geometric pattern. The side of the cube was calculated according to the size of the nanoparticles, and the distance between the nanoparticles is determined according to the characteristics of the materials (density of silver, with a value of 10.49kg / dm^3 and that of acrylic resin, with a value of 1.51kg / dm^3) and the concentration of nanoparticles.

From geometric point of view, each nanoparticle is situated at an equal distance of one to the other, in three directions: two horizontal and one vertical.The solid model is transferred into a finite element analysis program, where a 3D mesh is being created, and subsequently the stress distribution analysis performed.

The finite element analysis consists in two steps: modeling the structure /system and simulating factors acting on the system.

For the analyze it is necessary to define: the geometric field of the problem, the elements to be used, element's geometric properties, the element's connectivity and the physical constraints.

A mathematical model is developed based on analysis o fthe data in relation to the phenomenon of interest and define the problem to be solved. Data for the theoretical modeling are established at this stage seeking answers to a minimum series of questions concerning synthesis of the geometric structure, synthesis of the material properties, synthesis of the support and of the loads acting on the system and the result to the FEM analysis.

The geometric model is based on a cube, with the side corresponding to the diameter of the nanoparticle (table I) which will be located in the center of the cube.

Table no I. The cube size according to silver nanoparticle dimensions

AgNps diameter [nm]	AgNps volume [nm^3]	AgNps weight [g]	Concentration [%]	Resin weight [g]	Resin volume [nm^3]	Total volume [nm^3]	Side of the cube [nm]
20	268082.5	$2.812x10^{-15}$	5	$53.43x10^{-15}$	35621025	35889107	329.85
40			10	$25.31x10^{-15}$	16873117	17141199	257.84
60			20	$11.25x10^{-15}$	7499163	7767245	198.04

These structural units were arranged as it follows: four on the length, three for the width and four for the height, resulting in a final volume of 48 nanoparticles (fig.1).

This arrangement was elected due to limitations on items number that can be used in finite element analysis, but also for the accuracy of the results.

For the final results interpretation only the items located in the center of the structure will be taken into consideration.

FEM analysis consist in a mesh realization by splitting a solid volume into finite elements, of parallelopipedic or tetrahedral shape; each element behaves individually, with the same characteristics as the base material

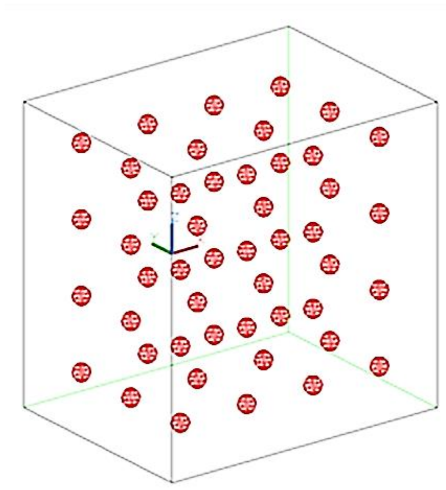


Fig. 1 Distribution of the AgNps into the acrylic resin

.

Depending on the action applied on every element, a specific load or temperature will be supported, and will be transmited to the adjacent elements through nodes.

For a better accuracy of the results a condition was imposed for the mesh realisation: the lenght between two nodes must be allways the same, according to the diameter of the silver nanoparticles; so, for a 60 nm diameter the chosen length was 2 nm (fig. 2).

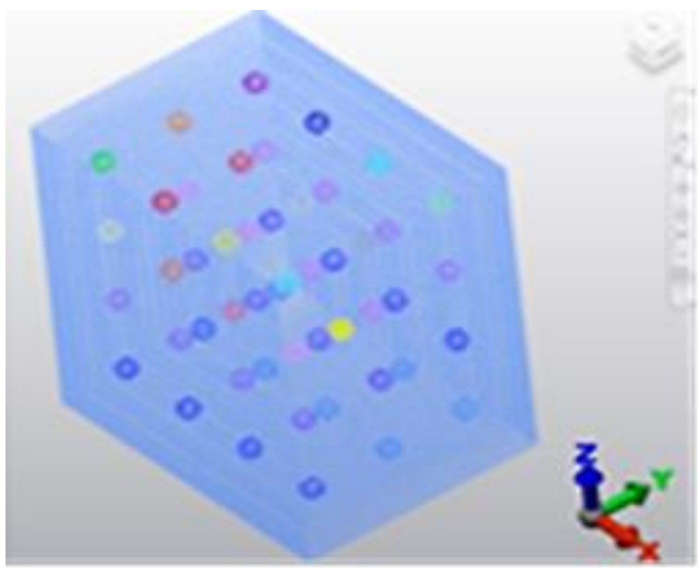


Fig. 2 Results of the meshing procedure

The material used in the finite element analysis was a composite consisting in AgNps incorporated in the acrylic resin matrix.

The material's properties used in the analysis were: the modulus of elasticity, Poisson's ratio, and density (table II).

Table II Material charactheristics for each component of the Finite Element Analysis

Element	**Modulus of elasticity [MPa]**	**Poisson's ratio**	**Density [kg/m^3]**
Acrylic resin	**2000**	**0,39**	**1,5**
Silver	**76000**	**0.37**	**10,491**

The load acting on a volume element of the composite material (the cube with 48 AgNps) is based on several biomechanical aspects of the mandibular movements.

The most important masticatory muscles are the masseter (on the external side of the lower jaw) and pterygoid muscles on the (internal surface of the mandible). For the load application we considered the moment of the maximum force developed by the masseter and pterygoid muscles during mastication (total value 16000 N.mm).

On the volume element of the composite material a pressure of 8 MPa was applied to the upper surface (yellow) and constraints were applied on the lower surface (green) (fig. 3).

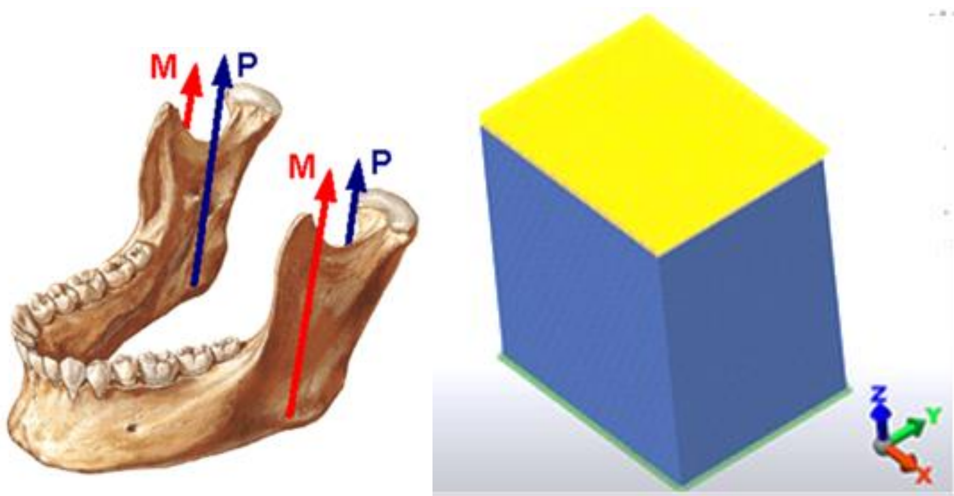


Fig.3 The action of pterygoid and masseter muscles on the mandible

The distance between two nodes must be always the same, according to the diameter of the silver nanoparticles. To calculate the average value of the forces, the force diagrams were registered for the two main categories of muscles, during a masticatory cycle (fig.4, fig.5).

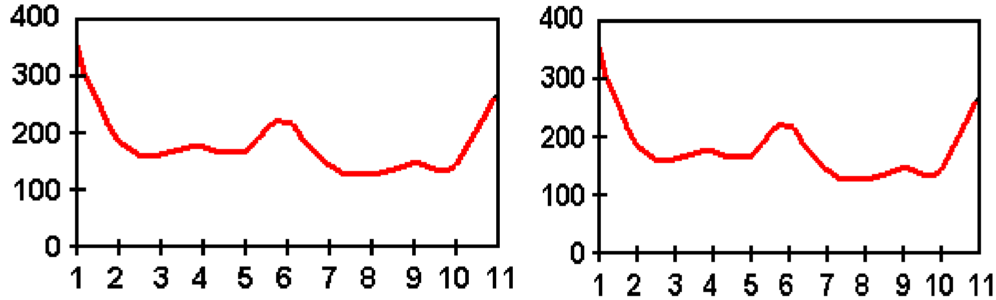


Fig. 4. Duration of the masticatory process for masseter muscles

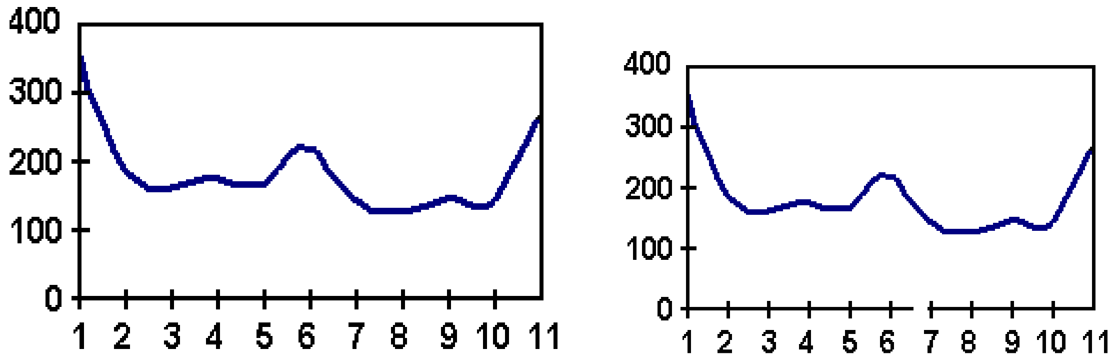


Fig.5 Duration of the masticatory process for pterygoid muscles

For testing the mechanical parameters, in the next step, we made two types of acrylic resins samples, commonly used in dental practice: a heat curing resin (Futura Basic Heat/Schutz Dental/Germany), indicated for full and partial removable dentures, and a self-curing resin (Futura Basic Cold/Schutz Dental/Germany), used for relining and rebasing removable dentures, and for making the acrylic elements of cast removable partial dentures.
The silver nanoparticles were 20, 40, 60 nm size, 0.02 mg/mL, in aqueous buffer, containing sodium citrate as stabilizer (Lot#MKBV9651V/Sigma Aldrich/USA) (fig.6)

Fig.6 Acrylic resins and AgNPs solution

A total of 80 rectangular cross-section specimens, 40 for each type of resin were made and divided into four groups, depending on the concentration of AgNps, as follows:
Group 1: **Control group**- HCR without nanoparticles
Group 2: HCR with 5% AgNps
Group 3: HCR with 10% AgNps
Group 4: HCR with 20% Ag Nps

Group 1': **Control group**- SCR without nanoparticles
Group 2': SCR with 5% AgNps
Group 3': SCR with 10% AgNps
Group 4': SCR with 20% AgNps

For specimens preparation the wax patterns were made of pink wax, 2 mm thickness, having the following dimensions: 75 mm length, 12.5 mm width (the extremities) and 4 mm in thickness (the central area) (fig.7).

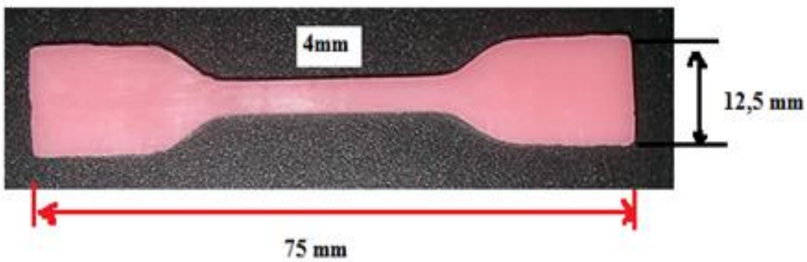


Fig.7 The specimen wax-up

The wax patterns were transformed in acrylic specimens according to the same technology used for acrylic dentures. They were first invested in dental stone (Elite Rock class IV/Zhermack) in order to obtain a mold (fig.8 a, b). After the mold isolation with a separating agent (Isodent/Spofa Dental), the acrylic resin pastes wereprepared, following the producer indications for each type.

For Futura Basic Hot the polymer/monomer mixing ratio was 2.5:1, and for Futura Basic Cold 10:7. The AgNps in colloidal solution was added to the monomer of acrylic resin by volume proportion in 5, 10 and 20% concentration, excepting the control group specimens.

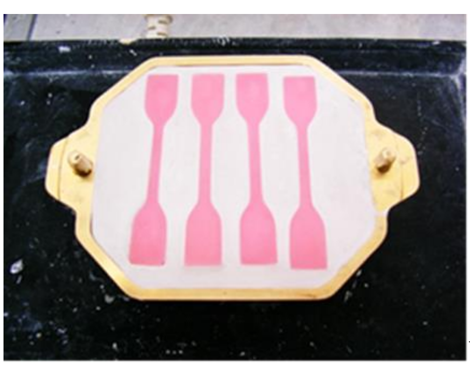
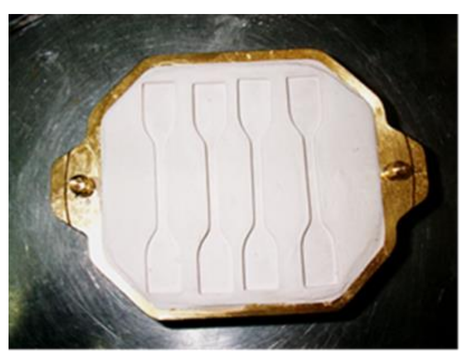
a.  b. 

Fig.8 a. Wax-up investing Fig.8b. Mold realization

The powder and liquid with nanoparticles solution were mixed into a porcelain jar (fig. 8 c), then the acrylic resin paste was packed into the mold at the dough stage, the flask was closed and pressed.

The polymerization technique was different, according to the manufacture recommendation: for the HCR the flask was immersed into a water bath and the temperature was rise up to 100°C, at 2-4 bar, during 20 minutes and for SCR reaction conditions have been 45°C, 2-4 bar, during 5 minutes.After polymerization the flask was opened and the specimens were removed from the investing material (fig. 8 d).

The specimens were washed with a stiff brush under running water to remove all gypsum traces, finished with fine carbide burs, polished to a smooth and glossy surface, and finally immersed in distilled water and stored at 37°C, for one week, before testing (fig.9).

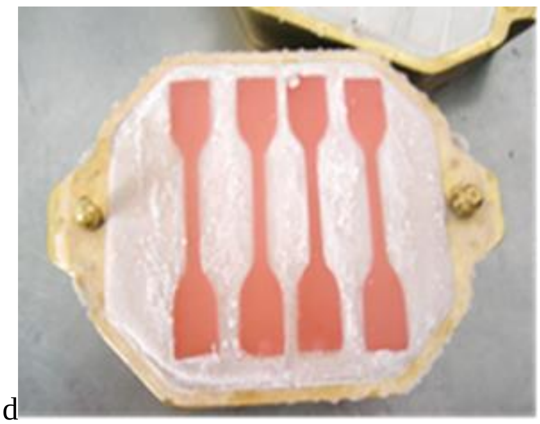
c.  d 

Fig.8c The acrylate preparation Fig.8d. Introduction of the resin in the mold

Fig.9 Acrylic samples after finishing and polishing

Tensile tests were carried out at room temperature according to the ISO 527-1: 2000 standard, using a computer-controlled testing machine (Instron 3382) equipped with a dynamic clip-on strain gauge extensometer (Instron 2620-601) for direct strain measurement. The rectangular specimens were placed and fixed between the grips of the testing machine (fig.10).

The tensile load was applied at a crosshead speed of 1 mm/min. Young's modulus (the slope of a secant line between 0.05% and 0.25% strain on a stress-strain plot), tensile yield (tensile stress at yield) and tensile strength(maximum tensile stress during the test) were determined.

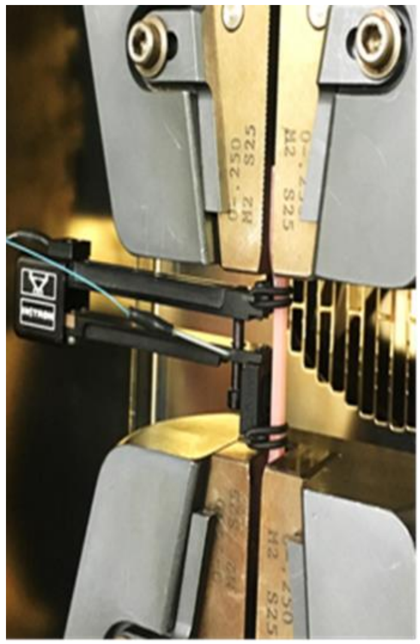


Fig.10 The specimen in the testing machine

Results

In the finite element analysis we determined two main features: Von Mises stresses and volume element deformations. Von Mises stress is a value used to determine if a given material will yield or fracture.The von Mises yield criterion states that if the von Mises stress of a material under load is equal or greater than the yield limit of the same material under simple tension then the material will yield. In order to visualise the stresses inside the volume element we used the option slice planes, which makes a section on a plane in the center of the volume element. Thus, it was established the section plane XZ (fig. 11, fig.12).

In order not to affect the analysis results, this plan can be setted to zero visibility. Basically, it is interesting to analyse the stress that occurs in the acrylic resin. The maximum load into the acrylic resin is 14 Mpa, lower than the maximum load supported by the acrylic resin, which is 30 N / mm².

Therefore, for all considered cases, the maximum load of 14MP will be imposed (in legend properties - as a maximum value visualized). So, it is possible to compare the difference between different values of loads, for each concentration.

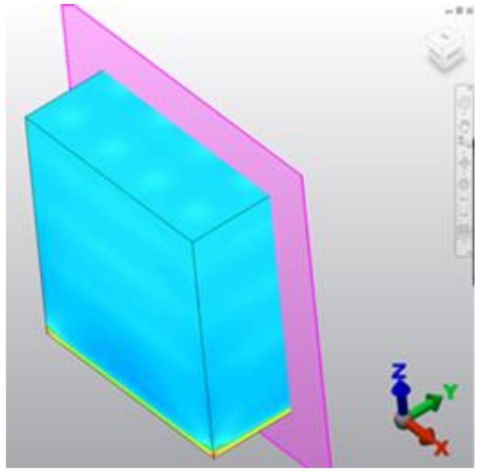


Fig.11 The section plane XZ in the center of the volume element

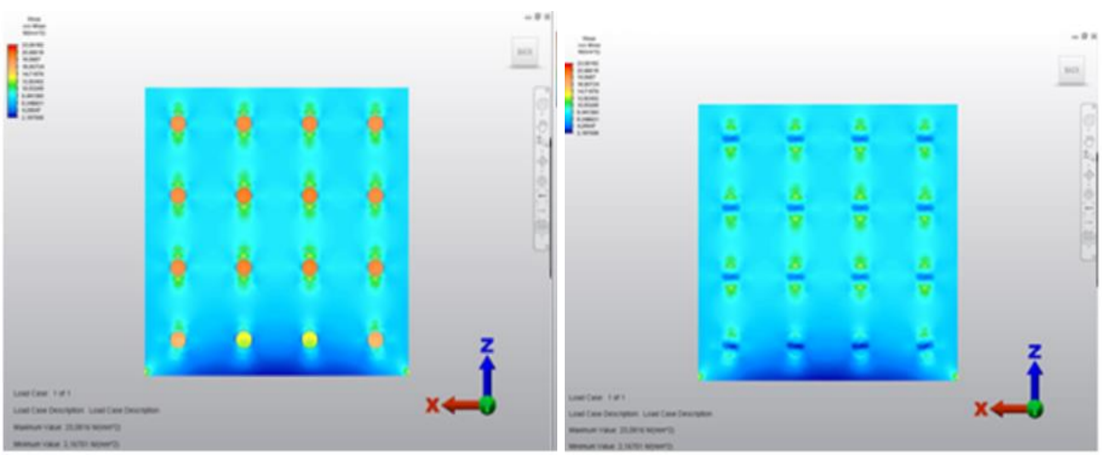
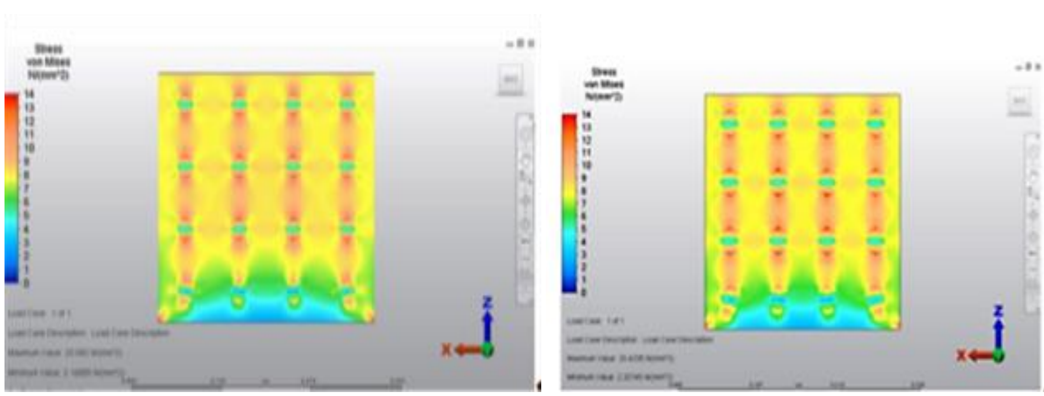


Fig.12 Tension value in section XZ

The images illustrate the stress distribution inside the acrylic resin, when the composite material contains AgNps, of 5, 10, 15 and 20% weight concentration (fig. 13 a, b, c).



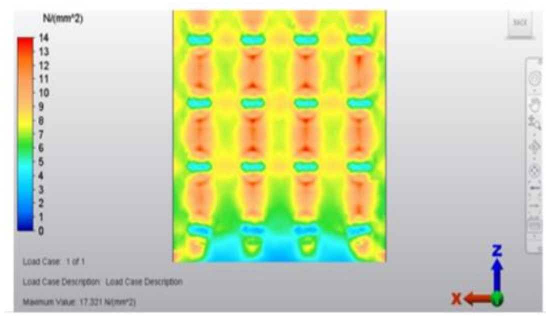


Fig.13.a. Von Missis stress values and deformation for resins with silver nanoparticles with a diameter of 20 nm, at concentrations of 5, 10 and 20%

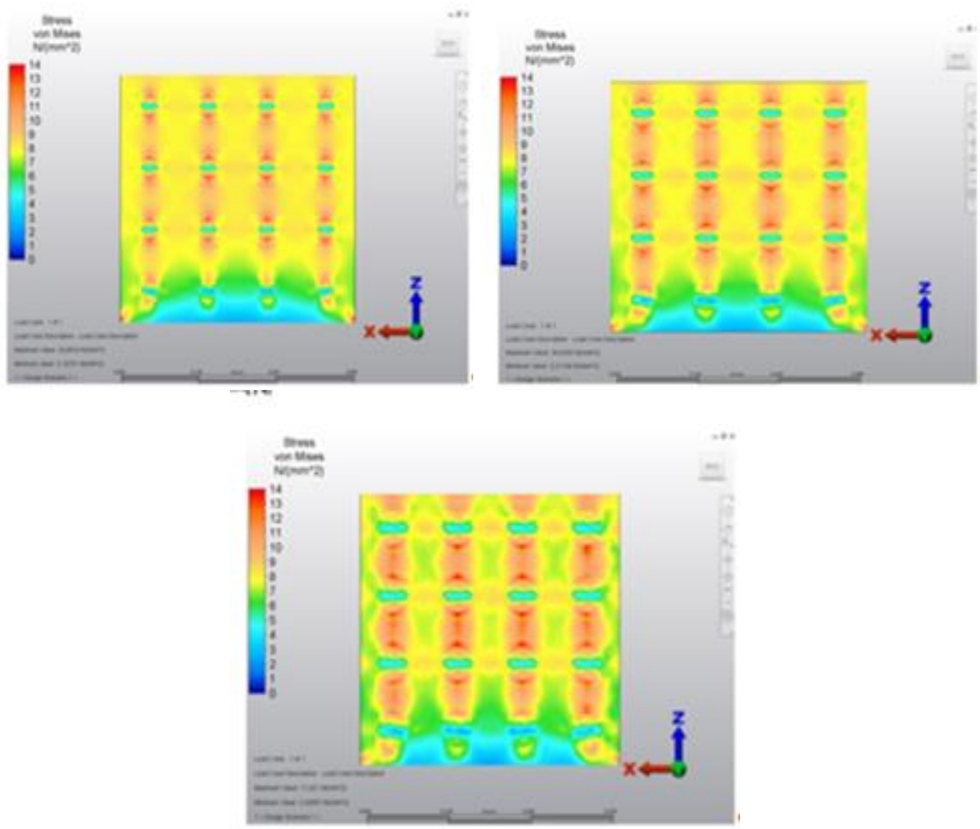


Fig.13.b. Von Missis stress values and deformation for resins with silver nanoparticles with a diameter of 40 nm, at concentrations of 5, 10 and 20

Comparing the results of this analysis, it can be noticed that, although the maximum amount of tension around AgNps has the same value, in the central area, which is relevant for the analysis (on columns 2 and 3 between rows 2 and 3) the lowest stress was found at 5% concentration, while the highest value of the stress corresponds to 20% concentration.

A lower loading is generating a lower stress into the acrylic resin, especially for the fatigue strength of the material under dynamic conditions. Another important aspect is concerning the nanoparticle density per volume unit

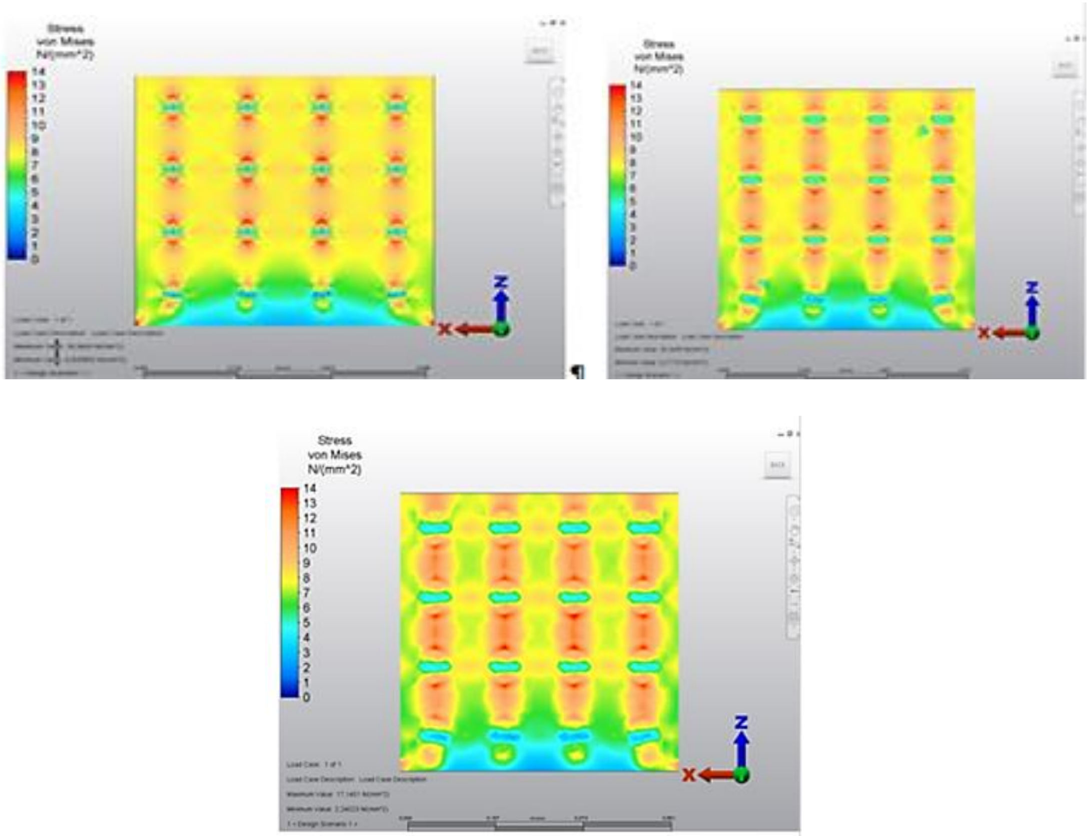


Fig.13.c. Von Missis stress values and deformation for resins with silver nanoparticles with a diameter of 60 nm, at concentrations of 5, 10 and 20%.

Taking into consideration the results it is obvious that the optimal AgNps concentration is 5%, from both biological and mechanical point of view.

The concentration and size of the nanoparticles are the factors that must be analyzed in order to establish changes in mechanical parameters.

Based on the results obtained within the FEA, we also performed the effective mechanical testing of the samples made from the two types of acrylic resins (table III).

Table III the value of mechanical parameters depending on the concentration and size of AgNPs

Sample	**Young modulus**
HCR without AgNPs	**2723**
HCR 5%	**2706**
HCR 10%	**2497**
HCR 20%	**2264**

Sample	Young modulus
SCR without AgNPs	**2795**
SCR 5%	**2122**
SCR 10%	**2341**
SCR 20%	**2161**

Tensile stress vs. tensile strain graphs for SCR and HCR samples are shown in figure no 14.

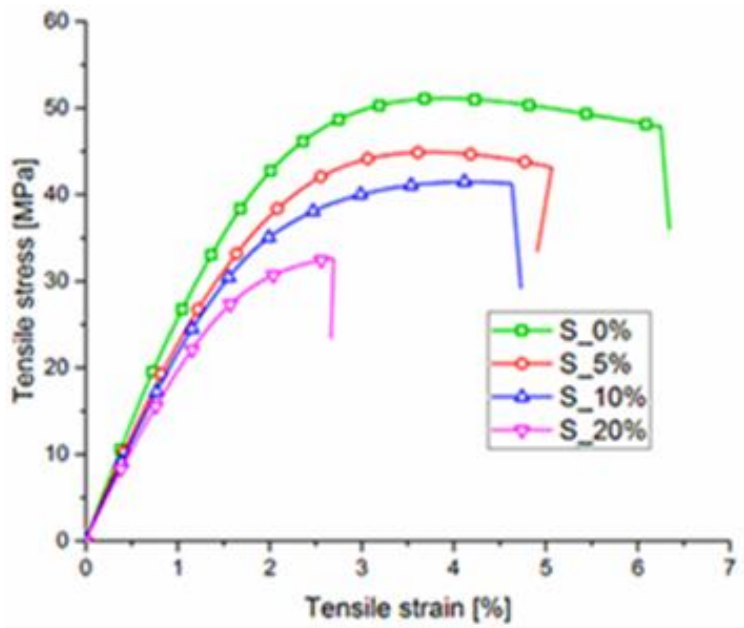


Fig.14 Tensile strength vs Fracture strength for the two types of resins

Under pressure, the resin samples first deform elastically, undergoing a reversible elongation; if the action of the force continues, the parts will deform plastically, irreversibly, after which they fracture; the value of the pressure at which the fracture phenomenon occurs depends on the mechanical characteristics of the material

Young's modulus (E), was calculated according to the Hook's law E = Ϭ / ε, as the ratio between stress (Ϭ) and deformation (ε) and describes tensile elasticity, or the tendency of an object to deform along an axis when opposing forces are applied along that axis; it is defined as the ratio of tensile stress to tensile strain.

A solid material will undergo elastic deformation when a small load is applied to it in compression or extension. Elastic deformation is reversible (the material returns to its original shape after the load is removed). At near-zero stress and strain, the stress–strain curve is linear, and the relationship between stress and strain is proportional to strain.

As can be seen the behavior of the two groups are quite similar, and all specimens exhibit brittle fractures (typical flat crack at break). A progressive decreasing in mechanical properties when the amount of AgNPs increases is obvious (fig.15) but the evolution is different.

At a constant pressure, the decreasing of Young's modulus demonstrates a more important deformation; the lower the Young's modulus, the greater the flexibility of the material, for total prostheses being not considered an advantage. The results were statistically processed by the method of two-way ANOVA dispersive analysis and statistical significance was set at $p < 0.05$ (fig.15).

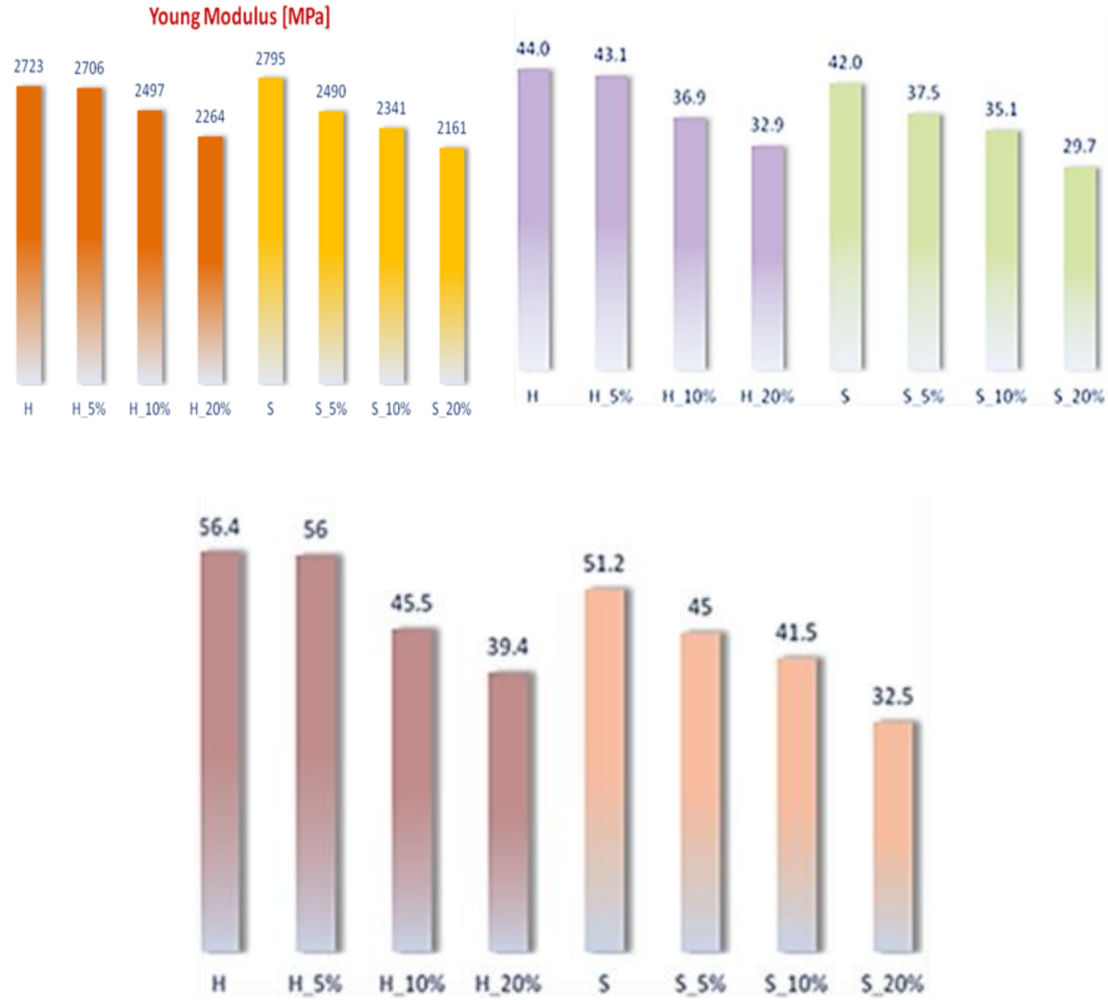


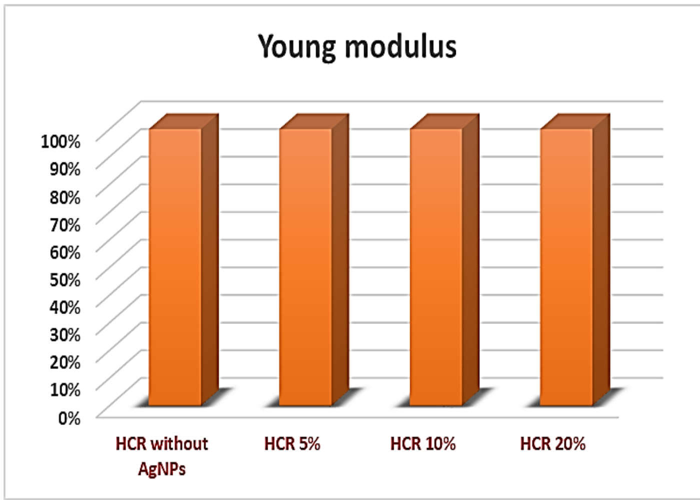
Fig.15 Values of Young's modulus

The results show in this case that for heat-curing acrylic resins there are statistically insignificant differences compared to the control samples at a concentration of 5% and significant differences at concentrations of 10 and 20%.

For the heat-curing acrylic resins, it is found that the samples with a concentration of nanoparticles of 5% have very similar characteristics to the control samples, the differences not being statistically significantly different ($p > 0.05$).

For the concentrations of 10 and 20%, differences of values are observed, both at traction and at fracture, statistically significant, in relation to the control samples ($p < 0.05$). For HCR samples we noticed that increasing the AgNPs concentration leads to a constant decrease of all mechanical features (fig.16).

Chladek reported that mechanical and physical properties of the composite are influenced by silver nanoparticle concentration.They also showed that mechanical properties of composites decreased by increasing silver nanoparticles. It has been demonstrated that addition of more than 5 wt% of the metal fillers into acrylic resin would reduce tensile strength ((Chledek G et al, 2013).



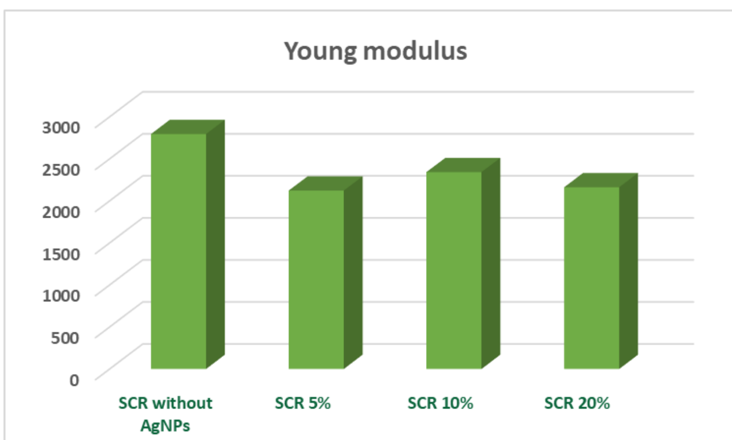


Fig.16 The mechanical behavior of the two types of resins

The specimens with 5% AgNPs showed very similar mechanical properties with the control group.

Self-curing acrylic resins have a significantly lower Young's modulus value compared to control samples at all three concentrations. For SCR samples we found a more pronounced decreasing of all mechanical features comparing to control group. It seems the lack of chemical bond between the inorganic material (AgNps) and polymer itself is the main cause of decreasing in mechanical properties which affects especially the SCR specimens.

Discussions

Silver nanoparticles have been extensively studied for their antimicrobial properties, which provide an extensive applicability in dentistry. Because of this increasing interest of these materials our studies aimed to analyze the impact of these nanoparticles on materials often used in dental laboratories - acrylic resins.

In literature, there has been a permanent debate regarding the utility of enriching dental materials with nanoparticles; considering the numerous reactions at the level of the oral mucosa in the case of wearers of mobile acrylic prostheses, more and more studies have been carried out regarding the introduction of silver nanoparticles into the structure of these materials, as a solution to these inconveniences.

What concerned the researchers was whether this antibacterial effect of the nanoparticles is not counteracted by the modification of the structure and material properties. Sodagar et al concludes in his research that the effect of AgNPs on the mechanical parameters of PMMA depended on several factors such as the type of acrylic resin and the concentration of nanoparticles.

Several studies have shown that after incorporating a certain ratio of antimicrobial agent the physical and mechanical properties of the acrylic resin may get compromised. Therefore, it is important to evaluate the mechanical properties of acrylic resins after incorporation of any material since complete and removable dentures are subjected to repeated flexural forces (Sarkar et al., 2021)

The concern for optimizing the mechanical properties of acrylic resins was permanent, but each method had its own drawbacks. A lot of other studies in the field show that silver nanoparticles optimize the mechanical properties of acrylic resins. The researchers show that nanoparticles are more effective at increasing the strength of these materials compared to fibers (Alhawiatan et al., 2020, Machado et al., 2007), and concluded that both impact and transverse strengths were increased by the addition of nanoparticles (Alhareb et al., 2016, Bahrani F et al., 2012). Also important are the size of the nanoparticles and their concentration, as well as the polymerization mechanism (Ali et al., 2008, Fan et al., 2010).

The increasing advancements in nanotechnology in terms of adding nanosilver particles to an acrylic base, the use of nanosilver particles has been preferred to silver powder because the nanoparticles cause better processing and smoother surfaces than the silver powder (Hamedi-rad et al., 2014).

The research also focused on analyzing the surface changes of acrylic resins enriched with silver nanoparticles, knowing that this parameter influences the biocompatibility and longevity of removable prostheses.

In order to obtaine results and conclusions as relevant as possible, the method of sample realization is very important; therefore, after comparing the different protocols, we did not opt for nanoparticles prepared in the laboratory, but for standardized commercial products, which have uniform dimensions and perfectly controlled concentration.

In our study we used two categories of resins frequently used in practice to make prosthetic devices – heat-curring and self-curring resins to test their characteristics after the addition of nanoparticles.

The results of this study are similar with these of our previous research on the effect of AgNPs incorporation into the dental resin.

FEA method is very helpful in analyzing the behavior of materials, allowing a very large number of attempts and a relatively correct prediction of the results.

According to our results in this research, the acrylic resins optimized with silver nanoparticles with the smallest diameter and with the smallest concentration show the least structural changes. If the biological criterion is taken into consideration, as primary, then the mass concentration of 10% can be used, where the number of nanoparticles is doubled, and the difference between the tensile stress values is insignificant.

However, the finite element analysis must always be corroborated with mechanical tests, in order to confirm or deny the conclusions obtained. After comparing the values for tensile stress and tensile strain, we were able to observe that indeed the small concentrations of nanoparticles do not influence the mechanical properties of the materials, and at the same time this concentration has an antibacterial effect.

Oyar P et al concluded that the incorporation of AgNPs affected the flexural strength of PMMA depending on the concentration of nanoparticles. The addition of large-sized nanoparticles to PMMA increases its flexural strength. Accordingly, adding AgNP with proper concentrations to PMMA may enhance the mechanical properties of denture bases used in clinical practice (Oyar P et al, 2018).

According to the results of some studies, the properties of the polymer nanocomposites have proven to be dependent on the nanoparticle (Sun J et al. 2011; Sodagar et al., 2013, Gaad et al., 2016).

The type of incorporated nanoparticles, shape, size, concentration and interaction of the nanoparticles with the polymer matrix determine the properties of the polymer nanocomposite. The modulus, strength, ductility, antimicrobial properties and aesthetic properties of PMMA have been improved by the addition of nanoparticles (Köroğlu et al., 2016).

The mechanical properties of polymer nanocomposites depend on the dispersion and adhesion of the fillers between the filler and matrix. The homogeneous distribution and good adhesion of nanoparticles in the resin matrix increase the flexural properties of the polymer nanocomposites (Akay et al., 2019).

Hamedi Rad. et al. investigated the effect of adding 5 wt% AgNPs into PMMA and the changes in thermal conductivity, compressive strength and tensile strength values of PMMA. According to the results of this study, an increase in thermal conductivity and compressive strength values, and a decrease in tensile strength values were reported (Hamedi-Rad et al., 2014).

Ghaffari et al. investigated the thermal and chemical effects of silver particles on PMMA. According to the results of this study, the use of 0.8 wt% and 1.6 wt.% AgNPs reduced the flexural strength and elastic modulus of microwave-polymerized acrylic resin. In addition, the glass transition temperature has been decreased by the addition of AgNPs into PMMA (Ghaffari et al., 2015).

Of course, there are variations in the results of the research, depending on the nature of the resin, the way the nanoparticles were obtained (commercial products or prepared in the laboratory), if they were introduced into polymer or monomer; but we can conclude that the results of this study can guide practitioners in accepting or rejecting this technology.

More research and clinical studies are required for the use of nanotechnology for oral health and long-term antimicrobial, mechanical, physical and clinical effects of nanoparticles on dental resins should be investigated in further studies.

Conclusions

AgNps incorporation aims to avoid or at least to decrease the microbial colonization of the acrylic dental resins In order to predict the optimal distribution and concentration of AgNps, we used a finite element analysis, revealing the stress field at the particle/matrix interface.

Our FEM study demonstrates that the best concentration that does not affect the mechanical characteristics of the acrylic resin is 5%.According to the biological criterion a 10% concentration can be also used, because the stress inside the material being not significantly different in comparison to the situation registered for 5% concentration.The FEM analisys should be accomplished by mechanical tests and in vivo experiments in order to sustain the final conclusions and to indicate a better antimicrobial material for the prosthodontic treatment.

Our study illustrates that incorporating AgNps in acrylic resins decrease the rigidity of the materials. According to this research, for optimal mechanic properties, it is indicated a lower concentration of AgNPs.

Within the limitations of this study, the mechanical properties of acrylic resins were influenced by the concentration in AgNPs.

The HCR specimens with 5% AgNps illustrated similar mechanical characteristics with the control group, so, this concentration can be successfully utilized with an optimal antimicrobial effect, without negatively influencing the behaviour of the resins.

2. EFFECT OF SILVER NANOPARTICLES INCORPORATION ON STRUCTURE AND SURFACE OF THE ACRYLIC DENTAL RESINS

Introduction

The exceptional broad antimicrobial spectrum of Silver has been known and used for hundreds of years. Silver Nanoparticles are clusters of silver atoms that range in diameter from 1 to 100 nm. Due to their antibacterial, antifungal, antiviral, and anti-inflammatory activity, AgNPs provide one of the most cost effective antibacterial agents for various applications: textiles, renewable energy, environment, electronics, food/ agriculture, health care and biomedical. Their unique chemical and physical properties and pronounced antibacterial activity, provide one of the most cost effective antibacterial agents for applications in medicine for: diagnosis, treatment, dug delivery, bone cements, cardiovascular implants, medical device coating, wound dressings, medical textiles, contraceptive devices, etc (Zhang et al., 2016, Albanese et al., 2012).

Induction of antimicrobial activity in dental materials has been widely a large concern in dentistry, their usefulness being proved in orthodontic adhesives, dental instruments, endodontics filling materials and prosthodontics. In prosthodontics, despite the continuous progress in material science, Polymethyl Methacrylate is still the most used material for denture bases. A common problem faced by the acrylic denture wearers is the denture stomatitis, which is related to the specific conditions of the oral cavity, the state of the patient’s immune system, but also to the PMMA surface characteristics, that facilitates the bacterial-fungal biofilm formation. The classic treatment for denture stomatitis is based on topical or systemic antifungal drugs, but this infection is often persistent, since antifungal resistance has been reported in Candida Albicans biofilm. So, the prophylaxis of dental stomatitis by AgNPs incorporation represent a challenge (Panáček et al., 2009, Wong et al., 2009). The antimicrobial effect of AgNPs was demonstrated to be directly proportional to the concentration and inversely proportional to their diameter. Normally, a high concentration leads to more effective antimicrobial activity, while particles of small size can kill bacteria at a lower concentration. Particles larger than 100 nm showed only a bacteriostatic activity, while smaller particles have bactericidal effect. The smaller the particles (l< 10nm), the greater the antimicrobial effect (because they can penetrate into the bacteria, not only on it's surface). Silver particles have been used as an addition to acrylic resin in order to improve its mechanical properties. Although adding 25% silver powder to denture base increases its thermal conductivity more than four times, it results in a significant decrease in the mechanical properties of acrylic resin, making denture more susceptible to breaking by an impact.In the past, micrometer-sized particles were used to improve the resin characteristics; however, these particles presented several drawbacks. Regarding advances in nanotechnology sciences and benefits of adding silver nanoparticles to the acrylic base, which leads to better processing and smoother surface compared to micrometer-sized silver powder, the use of silver nanoparticles is preferred. Among various nanofillers available the silver nanoparticles are the most widely used nanoparticles because of their ductility, electrical and thermal conductivity and antimicrobial activity. On the other hand, resin discoloration and high cost can limit its use (Dawadi et al., 2021).

The present study was conducted to evaluate the effect of the addition of silver nanoparticles at 2 and 0.2 wt% concentrations on compressive and tensile strengths of acrylic base. Our aim was to evaluate the structural changes and the thermal behavior of the composite material resulted after AgNPs incorporation into acrylic dental resins.

The results of studies on the effect of silver nanoparticles incorporation on mechanical parameters of dental acrylic resins are illustrated by the following publications:

1 .**Diaconu-Popa D**, Comaneci R, Tatarciuc M, Murariu A, Vițalariu AM. Influence of silver nanoparticles on mechanical properties of dental acrylic resins *Rev.chim. (Bucharest)* 2016; 67(1): 2016:2311-2313.
2.Vițalariu A, Tatarciuc M, Luca O, C Holban Cioloca C, Bulancea B, Aungurencei A, Aungurencei O, Raftu G, **Diaconu Popa D**. Structural and Thermal Changes in Dental Resins Enriched with Silver Nanoparticles. *Rev.chim. (Bucharest)* 2019; 70(2):591-595.
3.Viţalariu AM, Lazăr L, Buruiană T, **Diaconu D,** Tatarciuc MS. Studiu privind starea de suprafaţă a răşinilor acrilice in raport cu metodele de prelucrare mecanică. *Rev Med Chir Soc Med Nat Iasi* 2011; 115(2):542-547.
4. Viţalariu A, Tatarciuc M, Cotaie G, **Diaconu D.** In vitro testing – an esential method for evaluating the performance of dental materials and devices. *International Journal of Medical Dentistry* 2015; 5(2):54-57.

Materials and methods

In order to test the quality of the surfaces of resins enriched with AgNPs, we performed samples from the two categories of HCR and SCR materials. The technological algorithm followed exactly the same steps as in the case of making full dentures: They were first invested in dental stone (Elite Rock class IV/Zhermack) in order to obtain a mold. After the mold isolation with a separating agent (Isodent/Spofa Dental), the acrylic resin pastes were prepared, following the producers indications for each type.

The polimerization process was done under the same conditions: for the HCR the flask was immersed into a water bath and the temperature was rise up to 100°C, at 2-4 bar, during 20 min and for SCR reaction conditions have been 45°C, 2-4 bar, during 5 min. The samples were processed and finished in the same way as the processing of commplete acrylic prostheses.

For the analysis of the surface condition, the roughness and hardness were analyzed, and for the structural analysis we performed an analysis with the help of SEM and AFM. We also compared the changes in the characteristics of these two categories of resins enriched with AgNPs, during temperature variations.

On the very first step we tested **the hardness** of the samples obtained by the classical technology. Hardness is an extremely important parameter used in to the comparison of the restoration materials. It can be defined as the resistance to the superficial printing or to penetration; the hardness is, therefore, a resistance measure to plastic deformation and it will be expressed as the force related to the area unit of the print.

Hardness indicates the resistance of a material to cracking and to abrasion during mechanical stresses. There are many methods used to determine the hardness, but we chosed the Vickers method. This is a static technique of determining the pressure resistance exerted by a diamond pyramid, with the peak angle of 136º.

The Vickers hardness was calculated according to the formula:

$$\mathbf{HV = F/\,S\ x} \quad \frac{\mathbf{2F\ x}\ \dfrac{\mathbf{sin136^{o}}}{\mathbf{2}}}{\mathbf{d^{2}}}$$

where F is the stressing force, S is the area of the surface left by the penetrator on the specimen and d is the diagonal of the pyramid base. In order to test the Vickers hardness we used the standard Vickers microhardness device CV Instruments 400 DM (Tecnimetal)

Vickers hardness test was performed with a Micro Hardness Tester device, under a 25-g load and 30 s penetration. A total of three indentations were made at different points for each specimen, and the means of individual specimens were averaged. It was registrated the lengths of the diagonal immediately after each indentation, allowing a minimal time interval to elapse between making and reading the indentations, the elastic recovery of the diagonals after indentation was minimal1. The measurements in millimetres were transformed into Vickers hardness values using a conversion chart.

Roughness is an important characteristic of surface quality and can be assessed by determining the micrometric profile of the finished and polished samples.

Surface roughness is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough and if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

The shape and dimensions of the micrometric profile have an influence on the adherence and development of the bacterial biofilm at the internal surfaces of the acrylic prostheses. Diagramele au fost înregistrate cu rugozimetrul Mahr Perthometer M1 (fig.17).

The investigations carried out on the surface quality aimed at highlighting the variations of roughness corresponding to the samples.

Fig.17 Mahr Perthometer M rugosimeter

For each sample we calculated Ra, which represents the arithmetical mean of the absolute values of the profile deviations from the mean line of the roughness, and Rz the average of all values represented by the maximum height between the maximum and the minimum profile within the assessment length, for each sample (fig.18).

For the structural analysis in a first stage we would uset scanning electron microscopy (SEM). To highlight possible changes in surface three dimensional morphology caused by AgNps addition, high resolution scanning electron microscopy (SEM) were performed. SEM analysis is the appropriate method to investigate microstructural changes occurring in resins after AgNPs incorporation

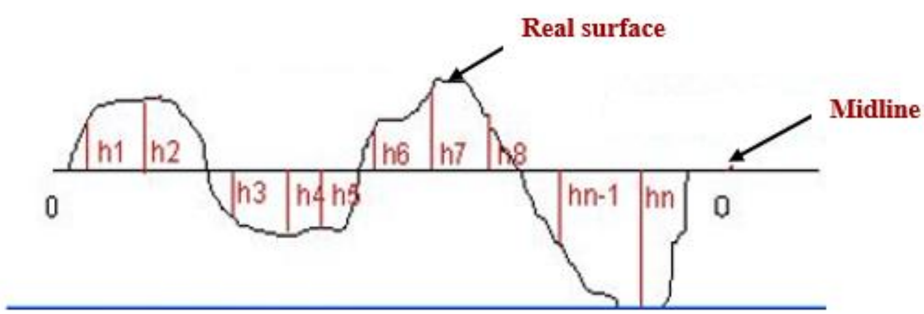


Fig.18 Maximum and the minimum profile within the assessment length, for each sample.

For the structural analysis in a first stage we would uset scanning electron microscopy (SEM). To highlight possible changes in surface three dimensional morphology caused by AgNps addition, high resolution scanning electron microscopy (SEM) were performed. SEM analysis is the appropriate method to investigate microstructural changes occurring in resins after AgNPs incorporation.

SEM produces images of a sample by scanning the surface with a focused beam of electrons that interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition. Due to the very narrow electron beam, SEM micrographs have a large depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of the sample (fig.19).

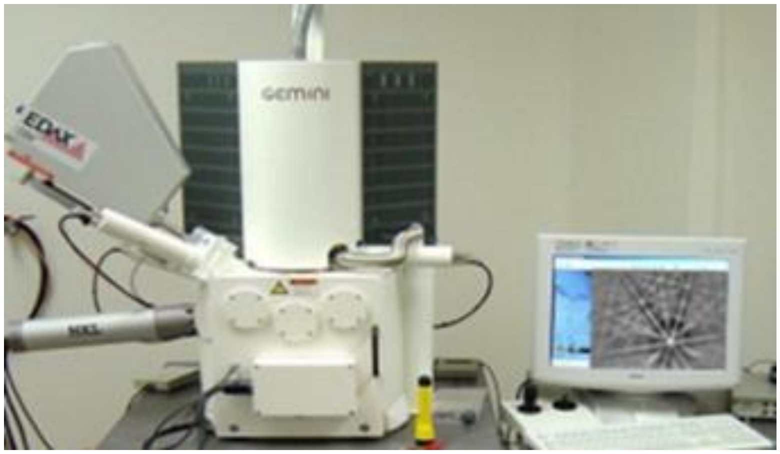


Fig. 19 Scanning electron microscope

In the second step an **AFM** depicts the topography of a sample surface by scanning a cantilever with a sharp tip over a region of interest. The force of attraction between the surface and the tip causes the cantilever to deflect towards the surface.

A laser beam is used to detect cantilever deflections towards or away from the surface. The structural analysis by using AFM wants to reveal – on submicronic and even nanometric scale -the AgNps integration into resin matrix by surface topography. To achieve the goal, prepared samples were examined using a NanosurfeasyScan 2 FlexAFM having a scan head capable of a maximum scanning range of 1 mm. 3D topography and 2D deflection over the scanning range and along a control line were obtained. To get an overall depiction of the nominated dental acrylic resins enriched with AgNps, a HCR's micron size analysis surface having 8mm scanning range was initially chosen for structural analysis.

Thermal characterization of the modified resins was performed by Differential Scanning Calorimetry (DSC) giving valuable information on possible induced transformations up to 65°C. DCS is the most frequently used method in the field of Thermal Analysis, being used to determine transition temperatures and enthalpy changes in solids and liquids. Thermodynamically, the driving force responsible for conducting a phase transition is the chemical potential, which is affected by temperature and pressure. When there is a gradient in the chemical potential between two phases, a spontaneous phase transition is produced from the higher chemical potential phase to the lower chemical potential phase.

Our purpose was to determine possible glass transition, decomposition and solid-solid transition. Thermograms over 20-60°C with typical temperature rate of 10K/min were achieved by using the Netzsch DSC 200 F3 Maia (fig.20). This device has two pans: the sample pan with the polymer sample, and the reference pan (empty). Each pan sits on top of a heater. The computer turns on the heaters, and heat the two pans at a specific rate, usually something like 10°C per minute. The heater underneath the sample pan has to work harder than the heater underneath the reference pan. By measuring just how much more heat it has to put out is what we measure in a DSC experiment.

Fig.20 Thermograph

Results

Acrylic hardness measurements will indicate the possibility of polymeric matrix degradation, which will result in decreased acrylic hardness, and increase the possibility of fracture, diminishing the longevity of denture bases.

Hardness is an important physical property of acrylic resins, enabling these materials to be used for manufactturing denture bases that resist forces, such as those arising from occlusion and mechanical denture cleansing, increasing the longevity of elderly peoples' dental prostheses Acrylic resins present a group of characteristics that make them acceptable and advantageous for pros-theses manufacturing, such as biocompatibility; possibility of being relined; low specific weight, solubility, cost and manufacturing complexity.

Nevertheless, these materials also present some less favorable properties, such as low thermal conductility, the presence of micro-porosities, low resistance to fracture and susceptibility to abrasion. Assuming that the hardness property indicates the ease with which the material is scratched or abraded, dental prostheses made of acrylic resins with low surface hardness will probably be damaged by mechanical brushing, compromising their surface roughness and allowing plaque retention and pigmentation, eventually compromising the aesthetic appearance and longevity of the dental prosthesis.

Hardness evaluation has frequently been used to predict dental material wear. Thus, the Vicker micro-hardness test is considered to be a valid method to evaluate rigid polymers by means of the ability of the material to resist the penetration of a specific load. This is a simple and effective way to evaluate the degree of conversion during the polymerization reaction after mixing the powder (spheres of poly methyl meth-acrylate and a small amount of benzoyl peroxide) with the liquid (methyl methacrylate with hydroquinone).

Although the Vickers micro-hardness testis considered a valid method to evaluate rigid polymers, a specific limitation of some Vickers hardness tests is the microscopic measurement of the hardness indentations after the indenter is removed. Firstly, these measurements can be affected by the limitations in the resolution of the optical system; secondly by the operator's per-ception and finally by elastic recovery of the material. Based on the results of this study, for both types of resins there is a statistically insignificant change in Vickers hardness values, regardless of particle size or concentration. Regarding the surface roughness, the values of the recorded diagrams (fig.21) were centralized and comparatively analyzed (tables III and IV)

Table III Centralization of surface roughness for heat curing resins

Heat- curing resin								
	0 nm		**20 nm**		**40 nm**		**60 nm**	
	Ra	**Rz**	**Ra**	**Rz**	**Ra**	**Rz**	**Ra**	**Rz**
-	**1.983**	**11.5**						
5%			**0.248**	**2.51**	**0.225**	**1.74**	**0.202**	**1.33**
10%			**0.25**	**2.1**	**0.209**	**1.69**	**0.228**	**2.06**
20%			**0.451**	**3.46**	**0.215**	**1.72**	**0.425**	**5.15**

Table IV Centralization of surface roughness for self-curing resins

Self curing resin								
	0 nm		**20 nm**		**40 nm**		**60 nm**	
	Ra	**Rz**	**Ra**	**Rz**	**Ra**	**Rz**	**Ra**	**Rz**
-	**3.374**	**16.3**						
5%			**0.302**	**2.07**	**0.264**	**1.99**	**0.375**	**2.54**
10%			**0.389**	**4.02**	**0.372**	**4.03**	**0.57**	**3.47**
20%			**0.281**	**2.51**	**0.473**	**3.74**	**0.826**	**5.05**

The results showed no changes in the roughness of the heat curing and self-curing acrylic resin surfaces AgNps, compared to control samples (fig.22)

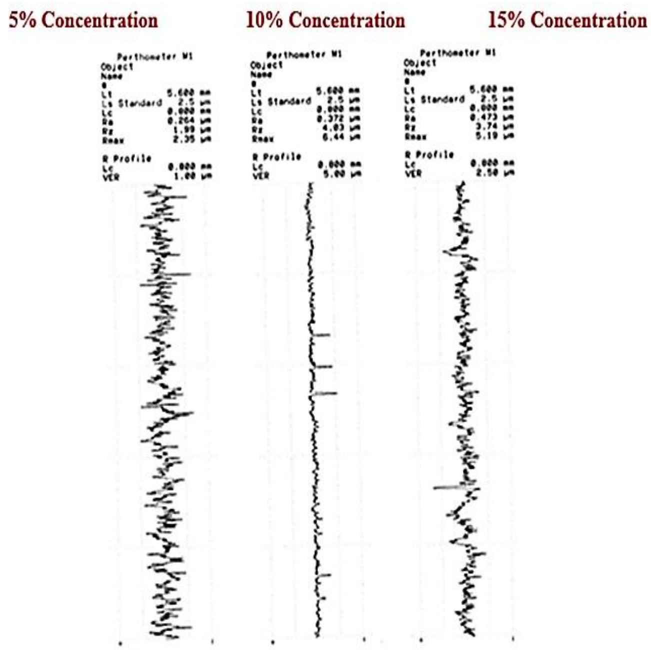


Fig. 21 Roughness diagrams

It is observed that the introduction of silver nanoparticles in the composition of acrylic resins does not influence the surface condition and implicitly does not affect the roughness of the materials.

It is very important to know this fact, because the quality of the complete dentures surface is a factor that influences their stability and longevity over time

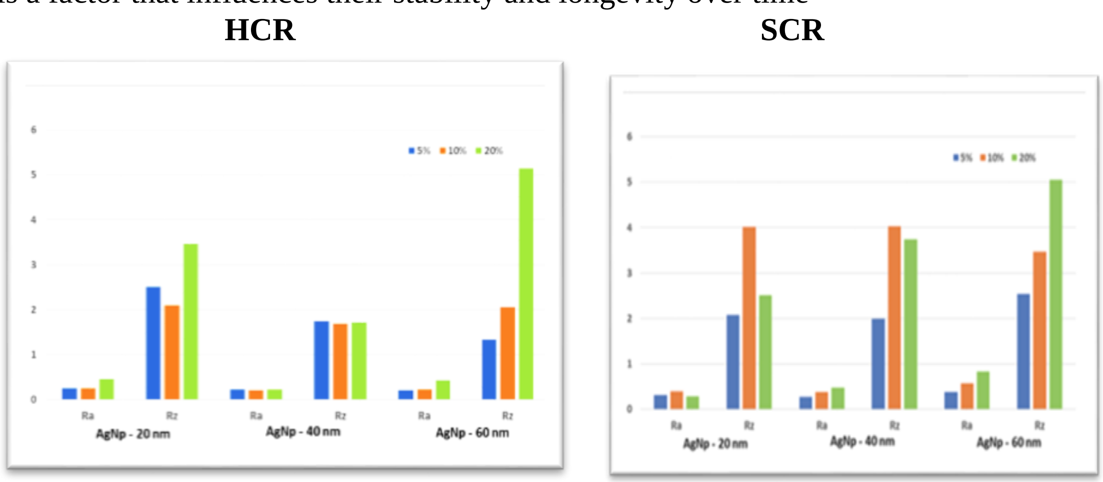


Fig.22 Comparative analyse of roughness values

The SEM images showed a homogenous dispersion of AgNPs into the organic matrix, without any dehiscence at the resin-nanoparticle interface (fig.23).

This demonstrates that the internal architecture of the resins is not modified following the introduction of AgNPs.

The homogenous structure of the material shows that the nanoparticles are perfectly integrated in the matrix and do not behave as impurities that can cause the appearance of internal tensions, which could propagate in the mass of the resin.There are no differences in the resin structure, regardless of the size of the particles or their concentration.

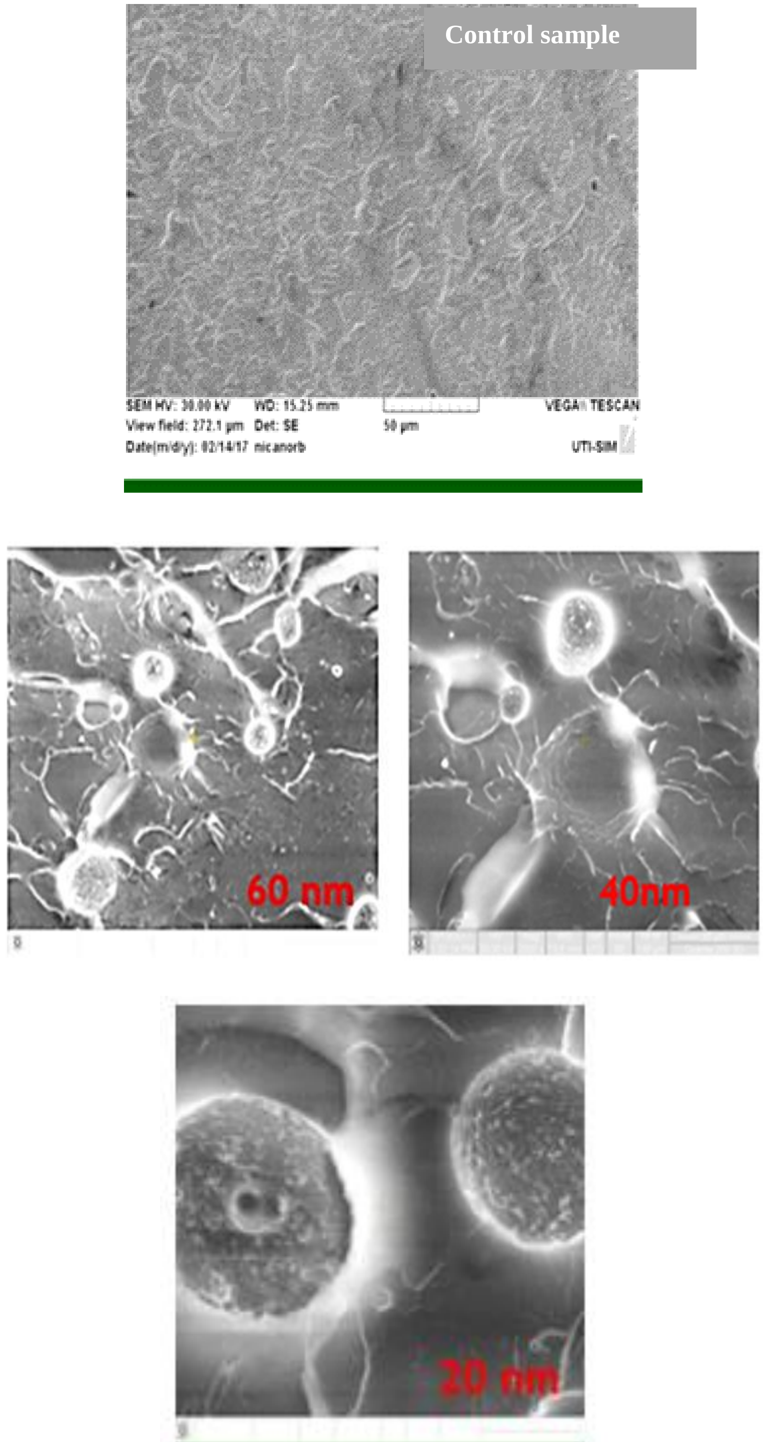


Fig.23 SEM images of the sample structure

To get an overall depiction of the nominated dental acrylic resins enriched with AgNPs, a HCR’s micron size analysis surface having 8 µm scanning range was initially chosen for structural analysis through AFM.

For 8 µm size analysis surface of HCR there are no steps or cleavage on the relief of the sample, revealing a homogenous surface.

The 2D deflection along the selection line shows a dimensional homogeneity. The vertical deviation of the roughness profile from the mean line is in range of +33.3 nm….-20.5 nm (the profile has 8.5 µm) (fig.24).

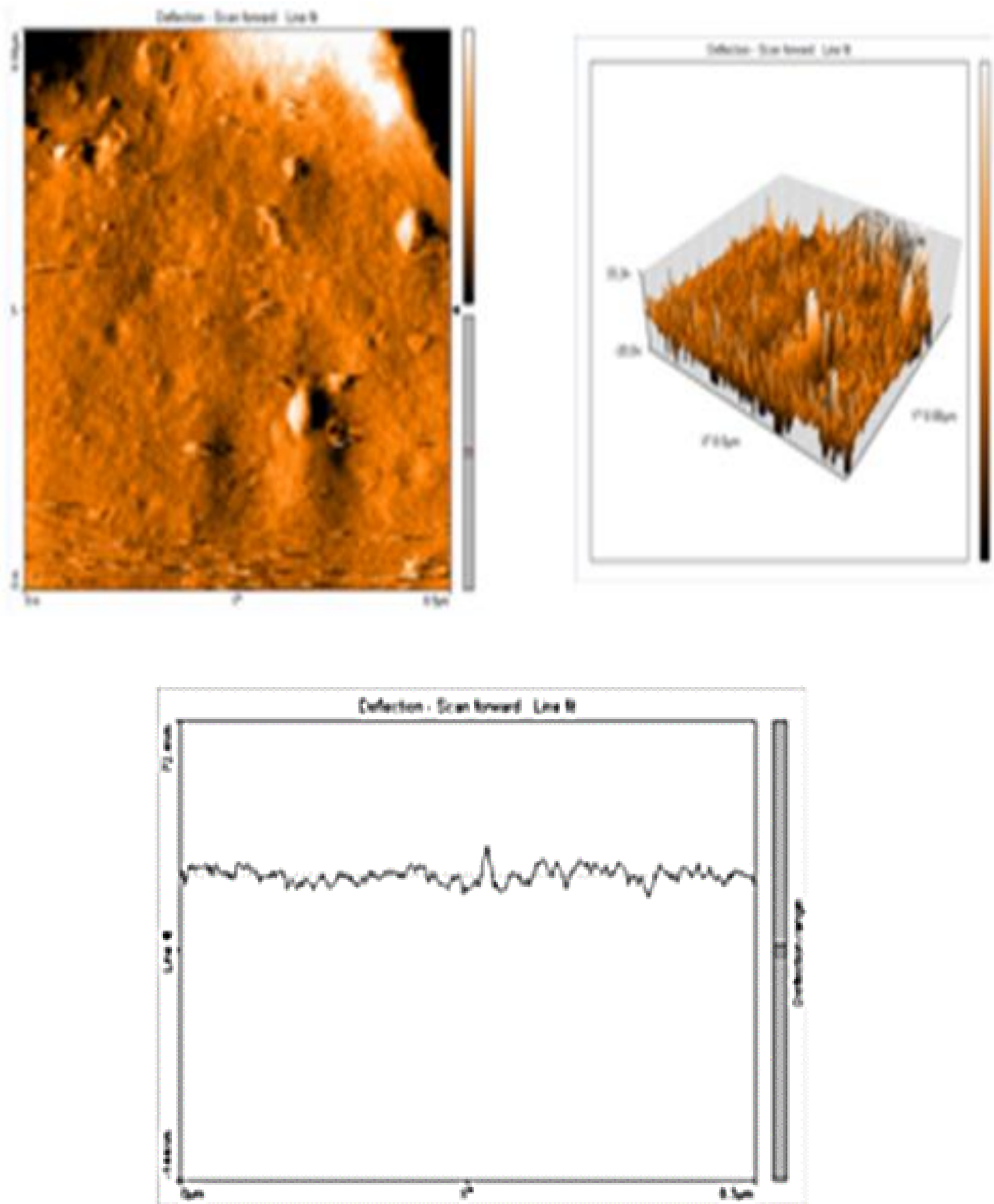


Fig.24 HCR sample

Similarly, for a detailed analysis, a SCR's micron size analysis surface having only 1μm scanning range was nominated for submicronic analysis. Even for the smallest area of analysis that device can scan, a homogenous surface profile is registered. Again, the 2D deflection along the selection line shows a surprising dimensional homogeneity. The vertical deviations of the roughness profile from the mean line is in range of +8.56 nm…-8.14 nm (fig. 25).

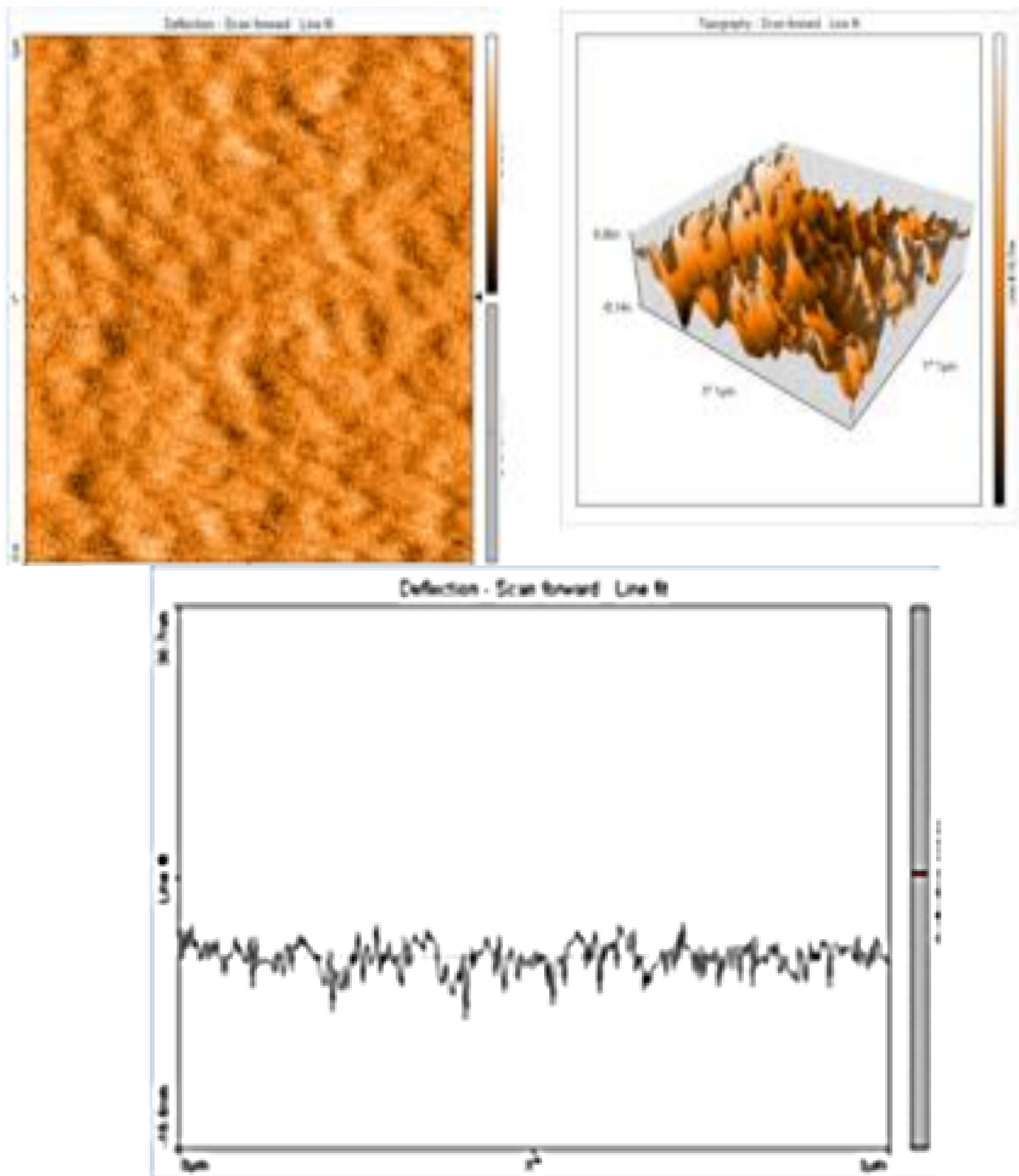


Fig.25 SCR samples

Differential Scanning Calorimetry (DSC) determines transition temperatures and enthalpy changes in solids and liquids being the most frequently used method in the field of Thermal Analysis.

Thermograms achieved over 20-60oC with typical temperature rate of 10K/min reveal no glass transition, decomposition or solid-solid transition by adding AgNPS both in SCR and HCR samples.

No significant phase transformation in dental acrylic resins or AgNPs de-bonding were reported, in other words, adding of AgNPs doesn't affect the cross-linking system of resins (fig.26).

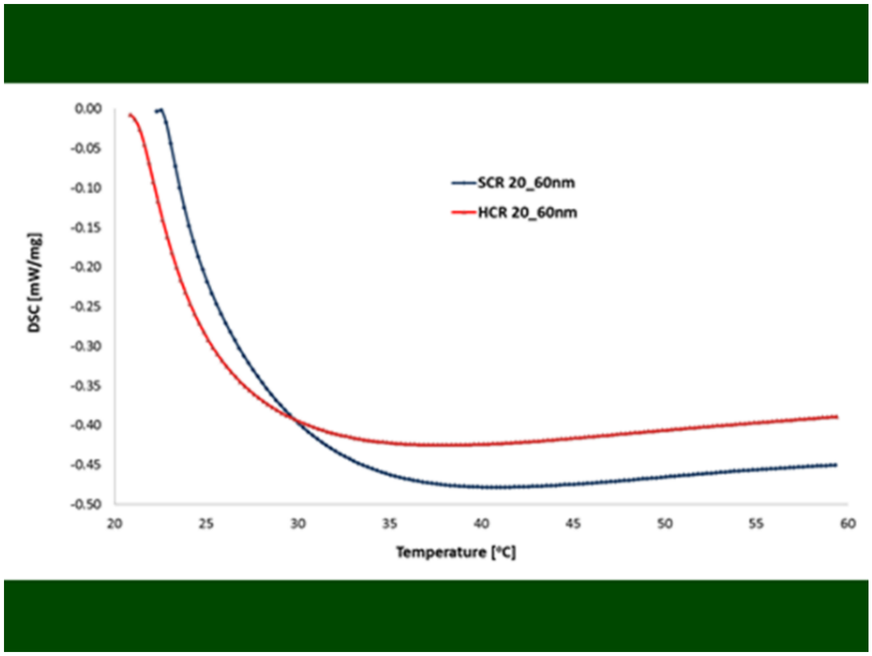


Fig.26 Thermograms

Discussions

The classic technology for full denture heat-curing acrylic resins realization involves a succession of clinical and laboratory steps, which must be well known and carefully observed.

The conventional technology of full dentures realization involves a multitude of laboratory stages, during which errors can occur; a mistake during a technological step is transmitted and amplified in the next step, and can eventually lead to an incorrect adaptation of the denture on the prosthetic area, incorrect occlusal repports or reduced mechanical strength. Researches has also shown that conventional acrylic resins, based on methyl polymethacrylate, in addition to the many advantages, also have a number of disadvantages (May et al., 2018, Pfeiffer et al., 2004)

Therefore, as new materials emerged and technologies evolved and diversified. Systems for injecting the resin into the mold have become increasingly popular in practice, a method that has several advantages over the manual introduction of acrylate (Machado et al., 2007, Diaz-Arnold et al., 2008)

Recent studies though have demonstrated excellent antimicrobial activity of AgNPs in materials such as nanocomposites, acrylic resins, resin co-monomers, adhesives, and implantcoatings.

Few clinical studies have investigated the therapeutic efficacy of AgNPs; among them are those that evaluated the anti-cariogenic potential of these particles.

Silver nanoparticles have demonstrated unique interactions with bacteria and fungi species, they are smaller in size and hence and possess physical, chemical, and biological properties that are distinctive from traditional bulk materials. Smaller particles and larger surface area provide potent antibacterial effects at a low filler level, diminishing Ag particle concentration necessary for its efficacy and avoiding negative influence on mechanical properties (Srivastava et al., 2016).

Therapy of denture stomatitis with antifungal drugs is mostly unsuccessful due to the multicausal etiology, resistance of microorganisms and insufficient concentration of the drug on the surface of the denture (Chandra et al., 2001). Denture cleansers are ineffective against typical denture plaque microorganisms, and also significantly damage acrylate dentures (Kiesow et al., 2016).

Recently, silver nanoparticleshave proven to be promising agents in antimicrobial treatment and there are certainly potential benefits to patient outcome from the use of AgNPs in dentistry (Peulen et al., 2011, Park et al., 2013). Even though the antibacterial activity of AgNPs is mainly associated to the release of Ag+ (which occurs by dissolution process influenced by conditions such as medium, ionic strength, pH, concentration of the dissolved O2, temperature, presence of complexing ligands, AgNP surface coating, shapeand size), it is worth mentioning that in some bacteria species its antimicrobial activity is also attributed to the nanoparticle itself, which enters the bacteria more effectively than Ag+ (Chaloupka et al., 2010).

The effectiveness of the antimicrobial effect is attributed to their physicochemical properties: ultra-small size, adequate surface-to-volume ratio and increased chemical reactivity (Kassaee et al., 2008)

Researches developed a PMMA containing 1 μg/mL of AgNPs and they compared this new compound to unmodified PMMA. It has been observed that PMMA-AgNPs specimens showed significantly less Candida albicans adherence compared to PMMA ($P < 0.05$), demonstrating the antifungical potential of AgNPs incorporated to acrylic resin. Besides that, they evaluated the activity of mouse fibroblasts and human lymphocytes, and it has been shown that PMMA-AgNP compound does not present cytotoxity or genotoxicity. These results suggest that the novel acrylic resin incorporated with AgNPs could be developed as a denture base (Acosta-Torres et al., 2013, Monteiro et al., 2012).

The main purpose of introducing these nanoparticles is to avoid inflammatory complications on the oral mucosa determined by its contact with the acrylic bases of the removable prostheses. But, besides this desired, the goal is not to modify in any way the characteristics of the resins, which have proven their qualities over time.

Acosta-Torres observed in a study that PMMA-AgNPs specimen showed significantly less Candida albicans adherence compared to PMMA, showing the antifungal potential of AgNPs incorporated to acrylic resin (Acosta-Torres et al., 2012)

Monteiro et al., concluded that the lower the volume of this AgNPs suspension, the lower the distribution and higher the dispersion of the nanoparticles in the PMMA structure. Silver was not detected by the the atomic absorption spectrophotometer used in this study, even after 120 days of storage in deionized water, suggesting that AgNPs are incorporated in the PMMA denture resin to attain an effective antimicrobial material to help control common oral infections in complete denture wearers (Monteiro et al., 2012).

Mahross and Baaroudi investigated the viscoelastic properties of acrylic denture base material incorporated with AgNPs according to the concentration (1, 2 and 5%). The results of this study showed that 5% nanoparticles of silver had significantly highest mean storage modulus E’ and loss tangent values followed by 2% AgNPs ($p < 0.05$)

For 1% silver nanoparticle incorporation, there were no statistically significant differences in storage modulus E’, loss modulus E”, and loss tangent with other groups, suggesting that the AgNP incorporation within the acrylic resin denture base material can improve its viscoelastic properties (Mahross et al., 2015).

In our studies, it was used nanoparticle concentrations of 5, 10 and 20%, mass percentages, with the aim of maximizing the antibacterial effect of the resins destinated for dental prostheses. The results are very encouraging and demonstrate that, even at a low concentration, the antimicrobial effect is efficient, and the resins do not change their characteristics

At a concentration of 10%, there are differences in the level of mechanical parameters, compared to the control samples, but these are not statistically significant.

If for heat-curring resins the structure and mechanical properties are not modified following the incorporation of silver nanoparticles, in for self-curring resins, which have a less stable structure, the differences compared to control samples are statistically significant, the greater the concentration of nanoparticles increases.

Conclusive studies on properties of acrylic resin on incorporation of silver nanoparticles have not been reported to date. The conclusions of our research are promising and of great importance for practitioners, but in order to have truly relevant results and to introduce this procedure in the protocol for the acrylic prosthetic devices, long-term clinical studies are also necessary, to confirm their antibacterial activity in the oral cavity conditions and keeping the mechanical parameters unchanged over time.

Conclusions

Overall, the incorporation of AgNPs into dental materials does not appear to alter the mechanical properties of these materials, and confers additional antimicrobial activity. However, there is some concern about the risk of an incomplete polymerization in resins and adhesives combined with AgNPs, as these nanoparticles may alter physical and/or chemical processes, which would impact negatively on clinical results and toxicity of these materials.

In addition, there is very few information about the influence of the Ag release and dissolution from the composite matrix on the physical, mechanical, and chemical properties of the composite over the time. Silver nanoparticles are uniformly dispersed in the organic matrix, without producing structural or surface changes.

The size of the nanoparticles does not influence the mechanical properties of acrylic resins, only their concentration

In the case of heat-curing resins, the concentration of 5% of silver nanoparticles does not significantly influence the biomechanical characteristics of acrylic resins, while at concentrations of 10 and 20%, significant changes in the tensile and compressive behavior are observed.

In the case of self-curing resins, the introduction of silver nanoparticles affects the mechanical parameters of these materials, the changes being all the more important the higher the concentration of nanoparticles.

3. RESEARCHES ON SURFACE CHARACTERISTIC OF CONVENTIONAL DENTAL ACRYLIC RESINS

Introduction

In prosthodontics, acrylic resin are used for denture bases, denture teeth, reline and repair of prostheses, provisional acrylic partial dentures, tissue conditioners and custom impression trays (Sabri et al., 2021)

The most used resins in dental laboratories, for removable dentures, are based on polymethyl methacrylateand are composed of numerous methyl methacrylate monomer units linked together to form a long-chain polymer.

As a result of the polymerization reaction, the resins undergo a series of dimensional change. Heat-cured acrylic resins shrink about 6% by volume and about 0.2% to 0.5% linearly (from one point on the denture to another).

According to the ADP, for a denture to be hygienically acceptable it should be nonporous because porosity will detrimentally affect the resistance of the material to staining, calculus deposition, and adherent substances. Porosity in PMMA also results in high internal stress and vulnerability to distortion and warpage.To evaluate porosity, microscopic observation, water absorption, photography, mercury porosimetry, have been used.

Since porosity reflects the quality of polymerization, studies for better polymerization techniques should be conducted.

The injection machines are equipped with a piston, which is operated manually or pneumatically and which allows the introduction of acrylate under pressure and its penetration into all the details of the mold. The process allows to obtain very precise, resistant and dimensionally stable prosthetic constructions, so with high longevity.

Manual injection systems are the simplest d3evicec for injection, which works on the principle of transforming the rotational movement into a slow translational movement (the piston is moved by rotating a lever).

In this technology, the acrylate, in the plastic phase (Acrypress) or liquid (Unipress), is introduced into a metal cylinder, which is then fixed in the injection device; by turning the lever, the piston is moved downwards and pushes the resin from the metal cylinder towards the mold. The resin cartridges are of variable sizes, depending on the amplitude of the prosthetic work.

Currently, full dentures can also be made from new generation self-curing resins, with cold polymerization, under 60 °C (Palapress, PalaXpress, Palapress Vario / Kulzer) that have comparable or even superior properties to thermopolymerizable ones: chromatic stability over time, resistance to bending, shock and elasticity. They can be molded by both pressing and injection.

Light-cured resins have revolutionized the technology of making removable dentures.

The Eclipse system is one of the most well-known and used technologies that use light-cured materials, with indications for making partial or complete removable dentures, temporary bridges and splints. This type of prostheses do not contain monomer, traces of metal, ethyl, propyl or butyl methacrylate (Mumcu et al., 2011)

This new system shortens a lot the working flow: the three types of resin used - for the base, for the teeth and for the finishing, are without monomer, are handled like wax and are available in four shades of color.

The system has many advantages: elimination of laboratory steps - investing, mold realization, preparing and introduction of acrylate into the mold, devesting; it also requires less material (the same resin is used for the occlusion rims and for the denture bas) and have a very good biocompatibility, compared to methyl polymethacrylate resins.

The base has a superior adaptation on the prosthetic field because the contraction at light curing is 3%, and at heat curing it is 7%, so the doctor's intervention on the final prosthesis is minimal or absent.

The color stability is high, the mechanical strength is maintained for a long time, and the However, the Eclipse system also has a number of disadvantages, which are good to know before choosing this material: the high price of the complete kit, the low viscosity of the resin for fixing artificial teeth, which makes handling difficult, incorporation of air bubbles during resin preparation operations, the need to duplicate the functional model, difficult processing of the prosthesis.

The aim of our research is to determine the main surface characteristics of acrylic resins (roughness, porosity and wettability) after the finishing and polishing procedures, and their influence on microbial colonization. The research consisted in analyzing by optical microscopy the morphology of the surfaces (the presence of mechanical impressions resulting from grinding), porosity and inclusions, following their size and distribution, as well as the surface condition after the glazing process, for six acrylic resins with different curing regime (self-curing and heat -curing) which were mechanically processed differently.

Also, using optical microscopy, the degree of bacterial colonization of five acrylic resins, frequently used in dental laboratories, with different polymerization regime (self-curing, self-curing under pressure and heat curing) were analyzed.

Our studies aimed at comparative analysis of the surface condition of different acrylic resins obtained by different polymerization methods, while corroborating the surface quality with the degree of microbial colonization.

The results of studies on surface characteristic of conventional dental acrylic resins are illustrated by the following publications:

1.Viţalariu AM, Lazăr L, Buruiană T, **Diaconu D**, Tatarciuc MS. Studiu privind starea de suprafaţă a răşinilor acrilice in raport cu metodele de prelucrare mecanică. *Rev Med Chir Soc Med Nat Iasi* 2011; 115(2):542-547.
2. Viţalariu AM, **Diaconu D**, Tatarciuc D, Tatarciuc MS. Factori implicaţi în colonizarea microbiană a răşinilor acrilice. *Rev Med Chir Soc Med Nat Iasi 2012*; 116(2):600-604.
3. Tatarciuc M, Vițalariu A, **Diaconu-Popa D.** Technological possibilities for full dentures realization. *Romanian Journal of Medical and Dental Education* 2020; 9 (4):95-102.

Materials and methods

The resins selected for the study are frequently used in dental laboratories for the dental prostheses realization: Castapress / Vertex, Prothyl Hot / Zermack, Rapid Simplified / Vertex, Duracryl Plus / Spofa Dental, Vertex - Soft / Vertex, Superacryl Plus /Spofa Dental. Thirty samples were made, divided into six groups (A-F) consisting of five plates for each type of resin.

The samples were made in the form of parallelepiped plates with a length of 50 mm, a width of 25 mm and a thickness of 2 mm. The wax patterns of the plates were transformed into final acrylic samples following the technological steps specific to each class of acrylic resin: heat-curing (B, C, D, F) and self curing under pressure (A, E).The finishing and polishing of the samples was done differently on each surface of the plates, but the speed and the time were the same (30 seconds, 1500 rpm). The surfaces were marked with the letters A-F and A'-F ', respectively. The mechanical processing was done with an extra-hard tungsten carbide burr, with fine granulation (yellow) for the surfaces: A, B, C, D, E, F and for the surfaces A ', B', C ', D', E ', the processing was done both with an extra-hard burr with extra-fine granulation of 53-63 μ , conical shape and with a diamond burr, with fine-grained (red) cylindrical shape. The final polishing aimed at obtaining a "mirror gloss" and was done with brushes and abrasive polishing powder (Poli-shing powder / Astar Fedent) and abrasive paste (High luster polishing paste).The F 'sample, being made of a resilient material, which is used only on the mucosal surface of the prosthesis, benefited from an easy processing with Vertex ™ Soft powder. The polishing was done with abrasive powder (Astar-Fedent) and abrasive paste (table no V).

Table V. Centralization of samples and technologies used

Sample	Product/Brand	Curing regime
A, A’	**Castapress/Vertex**	**30 minutes at 55º C and 2.5 bar**
B, B’ C (glazed) C’(glazed)	**Prothyl hot/Zermack**	**5 minutes from 80° to 100°C + 20 minutes lat100°C**
D D’(glazed)	**Rapid Simplified/Vertex**	**20 minutes at 100°C**
E (glazed) E’	**Duracryl Plus/Spofa Dental**	**30 - 40°C / 0.2 – 0.3 MPa.**
F’	**Vertex- Soft/ Vertex**	**3 hours at 70º C, then 30 minutes lat100º C**
F	**Superacryl Plus/Spofa Dental**	**The temperature rises in 30 minutes to 70ºC, 30 minutes remains at 70ºC, rises in 30 minutes to 100ºC, 30 minutes remains at 100ºC.**

Glazing was performed for the samples C, C', D' and E, with Bell Coat / K B Mutsumi glazing agent (light-curing glaze for acrylic resins and composite materials). A thin layer was applied with a brush, after the surface was previously dried very well, and then light-cured for four minutes.

Surfaces porosity measurement

The study consisted of optical microscopy analysis of surface morphology (presence of impressions after mechanical finishing), the porosity and inclusions, for determination of their size and distribution, as well as the surface status after glazing of acrylic resins studied. We used optical microscope Leica SM 2500 M, at x20 and x50 magnification. Storage and processing of data was made using Leica application. Initially, an inspection of the entire samples surface was conducted, to assess the surface homogeneity condition. Since on x20 magnification the surface condition of the entire area was homogeneous over, detailed analysis was performed at a x50 magnification, on three randomly fields.

Surface roughness (Ra) of the acrylic resin specimens was measured by atomic force microscopy (AFM). For hard materials roughness measurements with traditional diamond stylus profilers are adequate. The smooth surfaces consist often of soft materials such as pure metals (aluminium, gold, copper, etc.) or polymers and lacquers.

For roughness measurements on such surfaces diamond stylus profilers can not be used because they will scratch the surface and the measured value will be meaningless.
With AFMs the interaction force between the probing tip and the sample is very small and the spatial resolution is high. Additionally, for bacterial colonization roughness at nanometric scales becomes important. For this reason, roughness measurement by AFM is justified.

To determine the **wettability** of materials studied the contact angle measurements were performed. This angle is given by the surface tension of the liquid and the surface energy of the solid. A low contact angle indicates a good wettability. As the contact angle increases, wettability decreases.

To eliminate variability of surface porosity, each sample was finished and polished to obtain flat and very well polished surfaces. We aimed to compare wettability results, which was determined by calculating the contact angle (o), depending on the types of acrylic resins studied.

We also aimed to determine the **microbial load** of collected saliva and the microbial load of salivary pellicle on samples surfaces. Saliva was obtained from one patient aged 43 years, clinically healthy, which did not follow any drug therapy in the last three months and did not use oral rinses that could alter saliva's secretion or composition.
The working method consisted on disinfection of samples for one hour immersion in Zeta 1 Ultra solution and maintaining the samples in saliva for 24 hours. The contamination degree assessment was achieved by the method of growing microorganisms on Petri dishes, using nutritive agar (Merck, Germany) and the inoculum was obtained by repeatedly washing the prosthesis with 5 ml of sterile distilled water. For inoculum we used a volume of 100 ml inoculum / Petri dish, and in the brushes case we conducted the insemination both by washing it and by imprinting it in the agar. Incubation (24 hours at 37°C) was followed by a quantitative assessment of the microbial load using May Grunwald Giemsa panoptic coloring (MGG) of samples for determination of bacterial adhesion through optical microscopy (OM).

Result

In the case of Castapress / Vertex resin, surfaces A showed numerous pores up to 2 μm in size, evenly distributed in the material structure and large inclusions (up to 24.5 μm) with uneven distribution in the analyzed fields (fig.27). It was found that large inclusions have an irregular shape as opposed to the porosities characterized by the spherical shape. A 'surfaces were generally characterized by the absence of large inclusions and a low presence of pores, while maintaining the finishing lines.

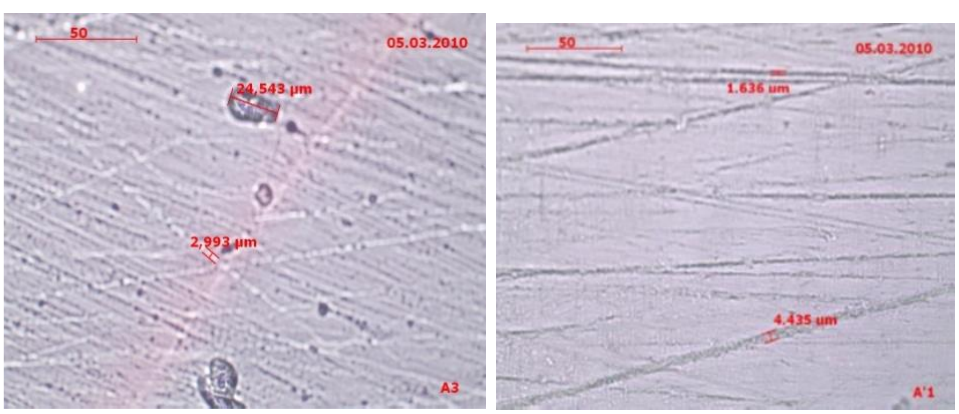


Fig. 27 Microscopic aspects of Castapress / Vertex resin X50

In the case of Prothyl Hot / Zermack resin, the surfaces B and B 'resulting from the two types of processing, were characterized by a reduced presence of pores on the surface. In the case of surfaces B, several mechanical impressions were highlighted (fig. 28).

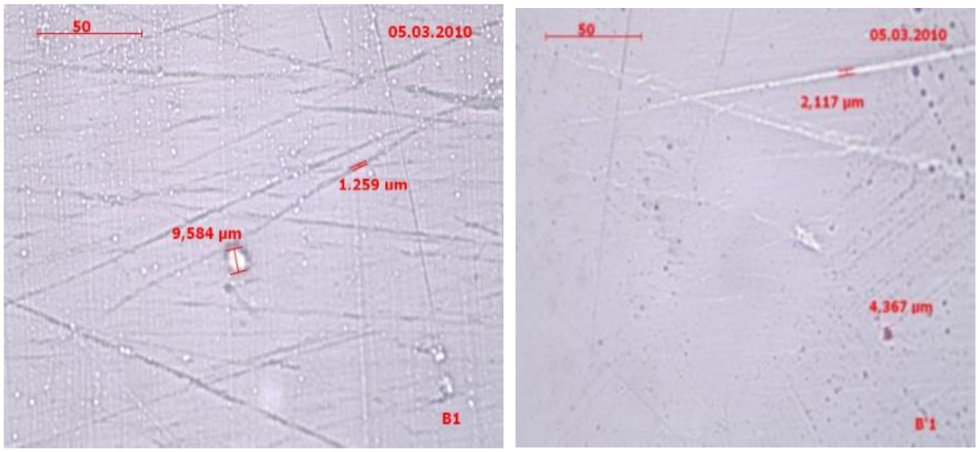


Fig. 28 Microscopic aspects of resin Prothyl Hot/Zermack X50

In the case of samples from Prothyl Hot / Zermack resin, in which both surfaces were glazed with Bell Coat, it was observed that after finishing with tungsten carbide burrs the glaze film covers the mechanical impressions produced by the abrasive tool, while presenting it the pores themselves are very small, approximately 2 µm (Fig. 29).

The surface C ', processed with extra-fine and diamond cburrs showed only small pores (about 3 µm) of the glaze film.

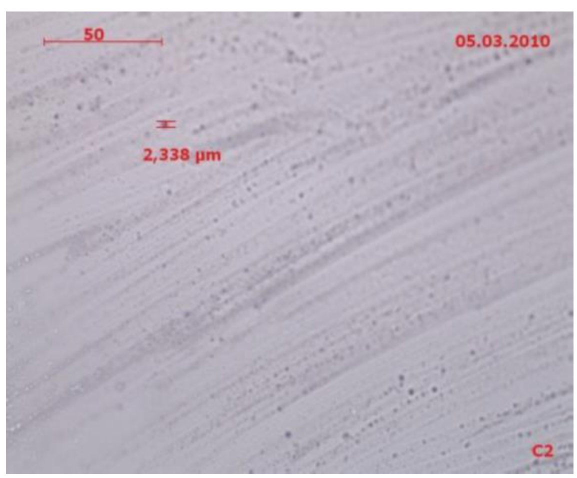


Fig. 29 Microscopic aspects of the C surfaces of Prothyl Hot / Zermack resin (glazed) X50

The same aspects were found in the case of samples made of Rapid Simplified / Vertex resin (fig.30).

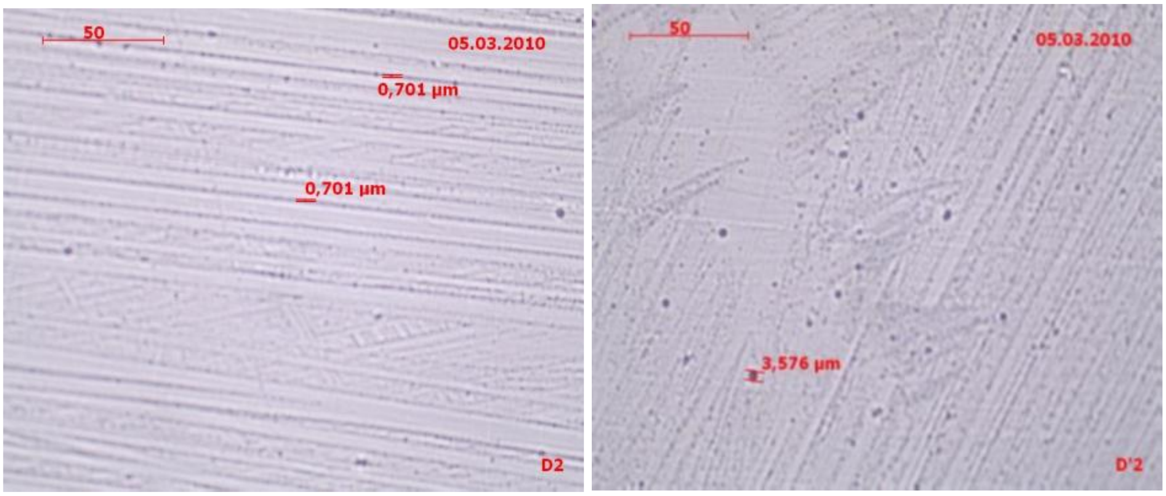


Fig. 30 Microscopic aspects of Rapid Simplified / Vertex X 50 resin surfaces (D'-glazed, D-unglazed)

In the case of Duracryl / Spofa Dental resin, the microscopic analysis of the glazed surfaces with Bell Coat showed that the large inclusions could not be covered by the glazing agent. In the case of images of E' surfaces (non-glazed rates), the presence of pores with dimensions of approximately 6.5 µm and the presence of sanding impressions were found (fig.31).

The images in the case of Superacryl Plus / Spofa Dental resin showed regular surfaces, with few pores, of small dimensions and the absence of impressions consequent to the mechanical processing.

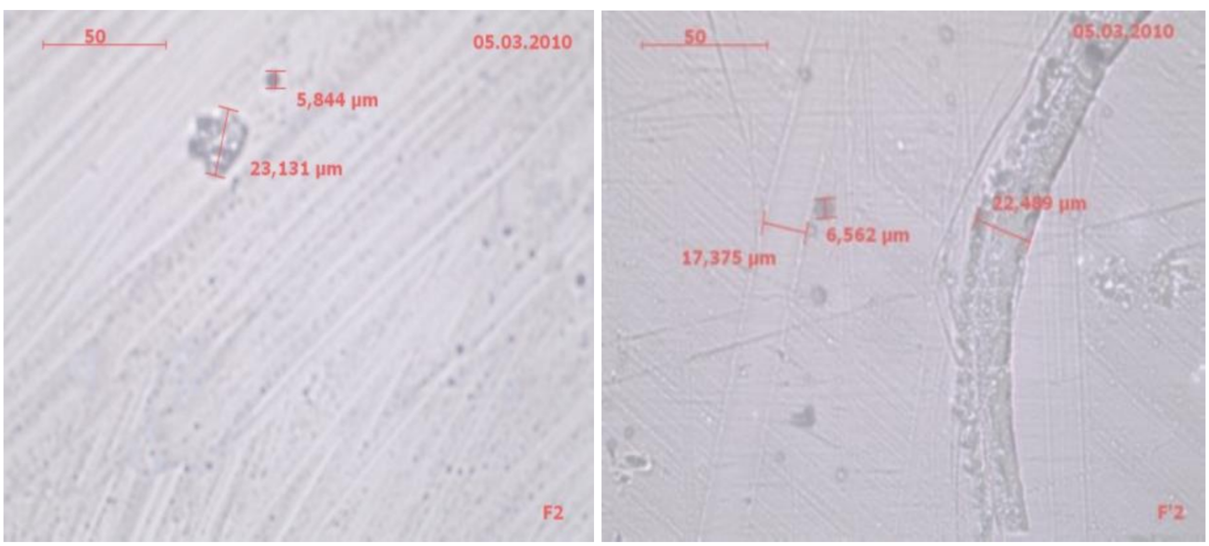


Fig. 31 Microscopic aspects of Duracryl Plus / Dental Sponge resin surfaces - E glazed, E unglazed X50

The F 'surfaces lined with Vertex Soft resilient material have a spongy texture due to the incorporation of air inclusions in the material (fig.32).

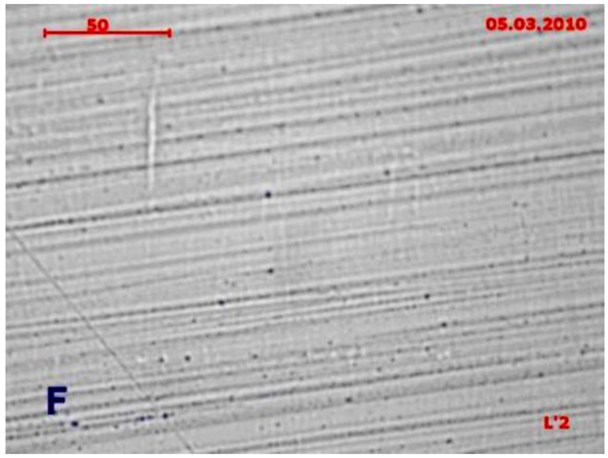


Fig. 32. Microscopic aspects of Superacryl Plus resin surfaces (F)

In the study of porosity, inclusions distribution was not uniform for all types of resins studied, the self-curing resins showing such inclusions and higher porosity, our results being similar to those of other studies.

The inclusions can be different in shape and size, distributed throughout the resin thickness, and have as main causes: improper monomer distribution, too large variation of the polymer molecular weight or lack of resin paste homogenization.

Regardless the porosity of the material, it was observed that the finishing and polishing to “mirror gloss” causes a reduction in the size and number of superficial pores, the obtained values being up to 10 micrometers in diameter.

Based on images obtained by optical microscopy we can say that the state of the surface after glazing presents superior qualities in terms of porosity and mechanical impressions. Samples of resilient material Vertex Soft, showed a spongy texture due to the air inclusions in the material (fig.33).

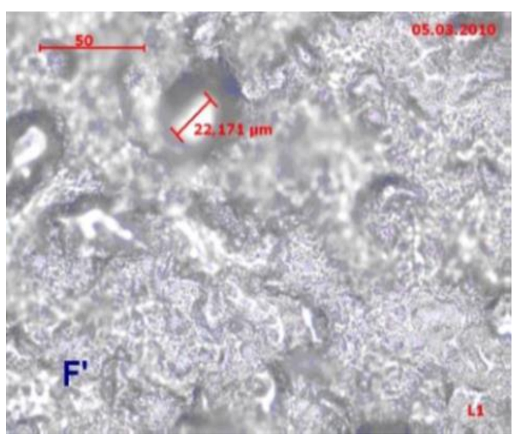


Fig.33 Microscopic image Vertex Soft surfaces at X 50 magnification

Regardless of the porosity of the material, it has been observed that processing and polishing to "mirror gloss" causes a reduction in the size and number of surface pores, the values obtained being up to 10 µm in diameter. On examination by light microscopy it was observed that by finishing with both types of burrs - extra hard and diamond - the porosity was lower than in the case of finishing only with extra hard burrs. At the same time, finishing only with the extra-hard burrs induces the existence of much more obvious mechanical impressions.

Analyzing these two qualitative aspects of the surface condition, we appreciate that the processing with extra-hard and diamond burrs induces a surface with much better qualities compared to the processing only with extra-hard burrs.

Regarding glazing, based on the images obtained by optical microscopy we can say that the surface condition after the application of the varnish layer has superior qualities to unvarnished surfaces in terms of porosity and mechanical impressions post-processing.

AFM analysis showed that the surface roughness was influenced to the greatest extent by the finishing and polishing procedures and to a lesser extent by the acrylic resin material (table VI)

Table VI. Ra values for acrylic samples

Material	Type of resin	Polishing method	Ra(nm)
Prothyl Hot	**Heat- curing resin**	**Conventional laboratopry polishing method**	**12.26**
Prothyl Hot	**Heat- curing resin**	**Conventional laboratopry polishing method-Glaze**	**5.33**
Duracryl Plus	**Self- curing resin**	**Conventional laboratopry polishing method**	**13.95**
Duracryl Plus	**Self- curing resin**	**Conventional laboratopry polishing method-Glaze**	**13.11**
Vertex Soft	**Resilient heat curing resin**	**Vertex TM soft Powder**	**121.63**

The highest smoothness, a mean surface roughness significantly below the threshold Ra=0.2 μm level, was produced by conventional laboratory polishing techniques combined with glazing of the heat curing samples.

There was no significant difference in mean average surface roughness (Ra) between glazed and non/glazed self curing resin specimens, yet a significant difference in surface roughness was found between self curing and heatcuring resins.

The mean value of Ra for resilient resin (Vertex Soft) was the highest from all samples in this experiment. Nevertheless, the values recorded were lower than the threshold Ra (0.2 μm) found in the literature.

The 3D topography could reveal the lack of homogeneity of the sample surface which is closely related to previous processing technique.

Wettability

Wettability is the tendency of one fluid to spread on or adhere to a solid surface in the presence of other immiscible fluids. To calculate this parameter we analyzed the contact angle values on the surface of each resin sample; the data were centralized in table VII.

We noticed that glazed samples have lower contact angle values, compared to unglazed resins, which demonstrates superior wettability.

Table VII Contact angle values correlated with polymerization regime

Sample	Polymerization/Finishing condition	Contact angle(º)
P	**Heat-curing/glazed**	**58.33**
P’	**Heat-curing**	**86.68**
D	**Self-curing/glazed**	**56.66**
D’	**Self-curing**	**53.57**
V	**Heat-curing**	**64.37**

Analyzing the contact angle values versus resins porosity, we noticed that the samples characterized by a high contact angle had increased porosity, except Vertex Soft samples, which, although it has a spongy texture, the contact angle value is below average (64.40).

The contact angle and sliding angle of the liquid on the solid surface are commonly used to characterize and measure the wettability of a particular surface. They have a wide range of values, which results in different wettability.

Although previous studies have shown that porous materials have increased wettability, the contact angle value (hence the wettability) is not necessarily conditioned by the porosity itself, but also by the hydrophilic or hydrophobic nature of the material.

Wettability is an important physical property of materials, being the result of bilateral influence between the surface characteristics of the material (dependent on the processing method) and its general characteristics (independent on the processing method).

Since wettability influences both bacterial colonization and denture retention, it is recommended to use materials with increased wettability for making dentures base.

Microbial colonization

The total germs number TGN /mL from saliva was 46 x 10^{10} and TGN values related to the acrylic samples were between 0.16 x 10^{8} cfu/cm2 - 12.1 x 10^{8} CFU/cm². (fig.34).

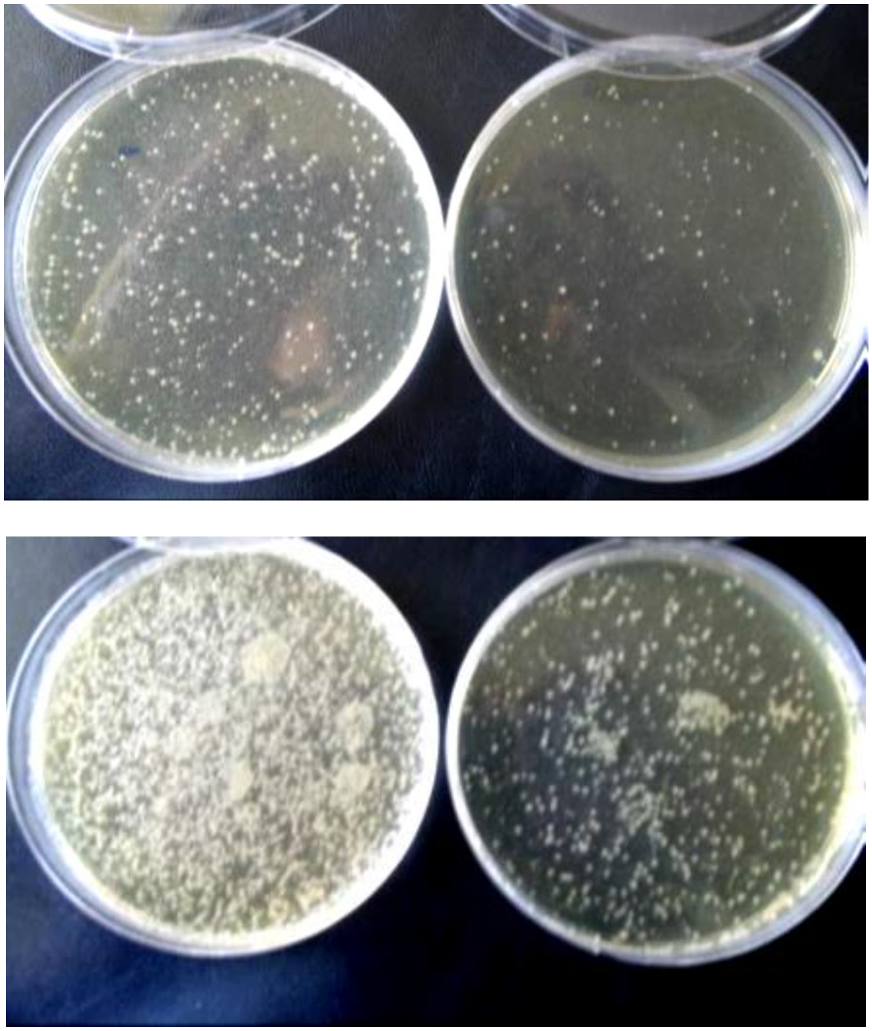


Fig. 34. TGN determination

The lowest value (0.16×10^8) was found in sample C (glazed), which demonstrates that although glazing cannot prevent bacterial colonization, it significantly changes the amount of microorganisms that adhere to the surface (Fig. 35a, b)

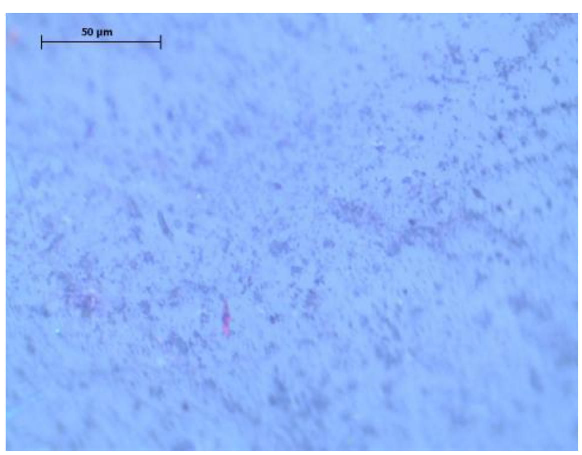


Fig.35.a.Sample C=$0,16 \times 10^8$ UFC/cm² (magnification X 50)

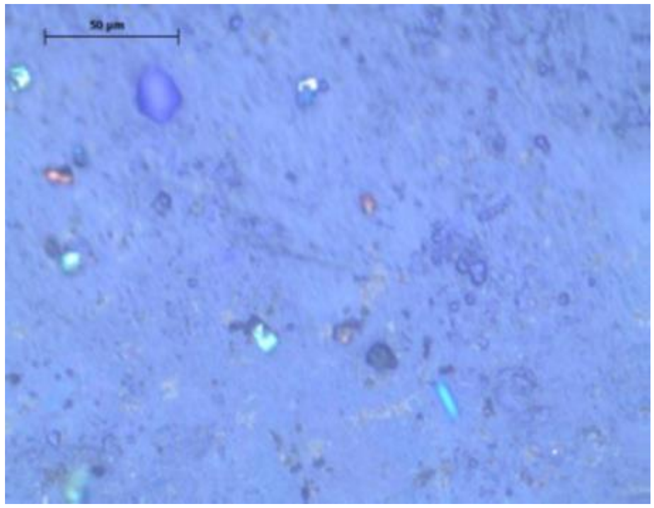


Fig.35.b.Sample C'=1,65x 10^8 UFC/cm² (magnification X 50

Correlating the results of bacterial colonization with the resin type and the finishing method used, differences are observed between the glazed and unglazed samples, in both Duracryl and Prothyl Hot resins. The highest microbial load value (12.1 x 10^8 CFU/cm2) was registered in resilient resin sample because of its spongy structure (table VIII).

Table VIII. The correlation between bacterial colonization, resin type and finishing method

Sample	**Resin finishing/polishing method**	**Bacterial colonization CFU /cm2**
A	**Vertex self- curing**	**1.76 x 10^8**
A'	**Vertex self-curing -glaze**	**1.68 x 10^8**
B	**Prothyl Hot heat-curing**	**1.46 x 10^8**
B'	**Prothyl Hot heat-curing-glaze**	**1.11 x 10^8**
C	**Duracryl self-curing-**	**1.65 x 10^8**
C'	**Duracryl self-curing-glaze**	**0.16 x 10^8**
D	**Vertex soft termopolimerizare, rezilienţă**	**12.1 x 10^8**
D'	**Vertex Soft resilient heat-curing resin**	**12.1 x 10^8**
E	**Superaryl Plus**	**1.01 x 10^8**
E'	**Superaryl Plus-glaze**	**0.83 x 10^8**

The highest colonization value was recorded in Vertex Soft samples (12.1 x 10^8 CFU/cm²).

Discussions

The surface characteristics of dental acrylic resins is considered an essential element for the clinical success of removable prosthetic restorations. Several authors (Barbosa et al., 2005, Garcia et al., 2004, Mondelli et al., 2005) have stated the importance of choosing correct parameters for surface roughness measurements.

Several studies has demonstrated in a clinical trial that a month after glazing the dentures showed a thinner film of plaque compared with unglazed resins. After 3 months reassessment showed a cracked glaze, creating microretentive areas that led to the accumulation of plaque. These findings made him to conclude that glazing efficiency is conditional on preserving the integrity of the deposited layer (Alves et al., 2007, Saito et al., 2000, Rahal et al., 2004)

In the literature, opinions on the type of relationship between surface roughness and bacterial colonization (direct or indirect dependency) are divided and some notice that "it is possible" that the surface roughness to provide an environment that promotes the initial attraction of early colonization. However, biofilm formation is dependent on many factors, including the bacterial species, the nature of the substrate and the ambient environmental factors

According to other research (Alves et al., 2007, Radford et al.., 2008) , on our study, regarding the correlation between polymerization type and microbial colonization, we noticed that self-curing acrylic resins have higher microbial load values, due to their elevated roughness and porosity.

The surface roughness of acrylic devices depends on the type of a resin as and on the finishing and polishing method (Alvez et al., 2007).

Studies on the effects of chemical and mechanical polishing on roughness in four types of acrylic resins used for denture bases, found that mechanical polishing produced better results (Rahal et al., 2004).

In a study of Xavier et al, .that evaluated the effect of chemical and mechanical polishing on the surface roughness of three acrylic resins from different manufacturers the conclusions was that mechanical polishing produced the lowest roughness values, followed by the control group and by chemical polishing (Xavier et al., 2006)

Other studies indicate that different types of polishing interfere in roughness13,14,15,16, and also lead to loss of dental material (Nishioka et al., 2006, Nagem-Filho et al., 2003, Campanha et al., 2005).

In our research, we found that for resins that have been glazed, the surface is more homogeneous, has no porosity and has increased wettability. So this method, applied after finishing the prostheses, would optimize their facial features.

Smooth acrylic resin surfaces are less receptive to bacterial colonization and dental plaque formation since plaque attachment is related to the surface roughness and presence of defects (Emami et al., 2014). Therefore, minimization of acrylic resin denture surface roughness, through glazing results in a higher wear resistance and reduction of biofilm formation (Emmanouil et al., 2002; Sesma et al., 2005; Shain et al., 2016; Kutlu et al., 2016).

Regarding the bacterial colonization of glazed acrylic resins, the results of our studies were higher comparing with the unglazed samples

Protocols for polishing dentures surface have been established, but the effect of polishing on surface roughness has not been studied systematically. Smooth and highly polished denture surface are of utmost importance for patient comfort and denture longevity, and it is desired for reducing microorganism’s retention. It can improve good aesthetical results, oral hygiene and low plaque retention, preventing oral diseases.

The aim of the polishing procedure of the denture is to make the denture glassy without changing its contour. For obtaining this aim, all scratches and rough areas must be removed. A series of progressive finer abrasive is used to produce a shiny surface on the denture.

The mechanical polishing procedure uses abrasives which produces wear of the surface in a selective controlled manner and this reduces the surface roughness of the material. Mechanical polishing is preceded by finishing using stone bur and sand paper in order to make the acrylic denture reach to the final form before polishing.

It has been observed that regardless of the porosity of the material, processing and polishing results in a reduction in the size and number of surface pores.

One factor that could potentially affect adhesion is surface roughness of a denture liner. Surface roughness has been shown to affect bacterial and yeast colonization of denture acrylic resin.

The conclusion of most researchers was that minimization of acrylic resin denture surface roughness, through glazing results in a higher wear resistance and reduction of biofilm formation (Emmanouil et al., 2002; Sesma et al., 2005; Shain et al., 2016; Kutlu et al., 2016).
Our results have shown that regardless of the type of prosthetic construction, self-curing resins have a less homogeneous structure, a rougher and more porous surface and a lower wettability. For practitioners, these conclusions are very important, because they must take them into account when opting for these materials, in order to make removable prostheses.

Wettability is another important feature of dentures, which largely depends on the quality of the surfaces, the higher the wettability of the material, the lower the microbial adhesion. o determine the wettability of materials studied the contact angle measurements were performed.

Biofilm colonization of dental biomaterials may degrade the material and roughen its surface, enhancing bacterial adhesion and initiating secondary caries and/or periodontal pathology. Surface wettability significantly influences biocompatibility response and is often calculated by measuring the material’s contact angle (Busscher et al., 2009).

To determine the wettability of materials it is necessary to analyze the contact angle of the surfaces; this angle is given by the surface tension of the liquid and the surface energy of the solid. A low contact angle indicates a good wettability and as the contact angle increases, wettability decreases (Auschill et al, 2002). A rough surface will always have a low wettability, so it is possible to predict an increased microbial adhesion to the surface of the prostheses.

The role of our research was to establish the most feasible method of finishing and polishing for conventional resins, to choose the most appropriate material for making removable prostheses and to find a method to reduce as much as possible the microbial colonization of the prosthetic devices; the research conclusions could establish a new processing protocol for removable acrylic prostheses for dental technicians. In our analyses, we focused on determining the characteristics of some categories of acrylic resins used very frequently in practice, for the realization of different types of prosthetic constructions.

Research must also be extended to the materials used in digitalsystems, subtractive and additive methods, in order to establish the optimal finishing method in their case as well, and also to evaluate the degree of microbial colonization, compared to the materials used in conventional technologies.

Conclusions

In our study, the distribution of inclusions was different for the studied resins the self-curing ones having more inclusions and porosities. The presence of inclusions can negatively influence the result of the mechanical processing of the surface; these defects occurobvious during the contact between the finishing burrs and the resin, determining the increase of the roughness of the material.

The use of the glazing procedure allows the optimization of the surface parameters, and the processing performed with extra-hard and t diamond burrs leads to the reduction of the number of mechanical impressions.

Following this study we can conclude that unglazed acrylic resins have higher values of porosity and roughness, and lower wettability values, favoring greater extent microbial colonization. Use of the glazing procedure allows the optimization of surfacecharacteristics.

Also, finished and polished specimens of self curing resin had a higher mean average of surface roughness and bacterial colonization than heat curing resins after the same surface treatment.

CHAPTER 2
TECHNOLOGICAL POSSIBILITIES FOR FULL DENTURES REALIZATION

State of art

Full denture is a treatment solution frequently used in complete edentulism because technological process is accessible and the materials used are generally low cost.

The complex pathology of the stomatognathic system induced by the total edentation offered the researchers a vast field of analysis, demonstrated in the literature by the multitude of information, systematized in numerous articles (Sharma et al., 2020, Sheth et al., 2018)

Most often, the dento-maxillary dysfunctions are generated by the loss of teeth, by odontal or periodontal damage. The higher the number of missing teeth, the more important the imbalances will be and will lead to other disorders, at the level of the temporomandibular joint or at the muscular level, with consequences on the position of the remaining teeth, on the occlusion, on the aesthetic aspect, on the patient's psyche and his social integratione (Radke et al., 2012)

Complete dentures arein contact with a large area in the oral cavity and the insertion of a prosthetic construction of such amplitude does not only suppose the restoration of the altered or lost functions but also the creation of a new balance between all elements of the stomatognathic system. The treatment planning, having previously the informed consent of the patient, is a fundamental point for the success of a dental treatment (Albaker et al., 2013, Marlière et al., 2018)

The choice of the optimal therapeutic solution must be based on a correct and complete clinical examination, on the results of the general, regional and local complementary examinations, on an objective evaluation of the patient's wishes and expectations. The difficulties of choosing a therapeutic strategy consist in achieving a balance between meeting the patient's requirements and the possibilities offered by the clinical situation (Foong et al., 2019).

Although, from a technological point of view, full denture is easy to make (the technique being simple and the laboratory does not require high-performance equipment) a number of problems arise when adapting it, due to important changes in the elements of the stomatognathic system and the installation of major imbalances (Suja et al., 2015).

Analyzing all the elements in the prosthetic area and establishing positive and negative clinical and biological indicators, the dental team will know what the therapeutic strategy is, during the stages of making the full denture and will be able to establish exactly the indications and contraindications for this type of prosthesis (Nitschke et al., 2021)

The material choosen for complete denture realization is very important, in order to have an optimal adaptation; therefore, implicitly, the appropriate technology must be known in detail, in order to avoid errors during the clinical and technological steps. The continuous evolution in the field of dental materials has led to the production of non-acrylic resins, clearly superior to classical materials (Mistry et al.. 2018, Schwindling et al., 2016, Aslanimehr et al., 2017).

In certain clinical situations, the acrylic denture, in its conventional version, does not meet all the requirements or fails to properly restore the functions, due to certain features of the prosthetic field. Therefore, it is necessary to know all the possibilities of treating complete edentulism, in order to be able to choose the optimal therapeutic option (Ravalec et al., 2020).

There are situations when, in order to increase the resistance of the prosthesis, it is necessary to reinforce the base with metal nets or with fibers or resin nets, that considerably improves the mechanical characteristics of the denture. Or, in some cases, we can restore the dental arches choosing as a treatment option tooth supported or implant supported overdenture. In order to determine the most correct therapeutic solution it is necessary to evaluate the characteristics, advantages and disadvantages of each prosthetic restoration (Idzior-Haufa et al., 2021, Keshk et al., 2107)

The major concern in complete edentulous therapy is the restoration of facial aesthetics according to biological and biomechanical behavior of the individual and to the patient's needs and desires. Therefore, it requires the development of an artificial substitutes which gives wearer the feeling of existence of his natural teeth, in the context of psycho-affective personality, preserving the patient’s aesthetic characteristics (McCunniff et al., 2017, Santos et al., 2015, Roumanas, 2009)

The full denture represents the therapeutic solution used in the treatment of complete edentulous, due to the numerous advantages: easy-to-achieve technology, rapid and optimal resumption of stomatognathic system functions, very good biocompatibility, the possibility of optimization or repair. At the same time, the disadvantages of these prosthesis (the atrophy of the alveolar ridges, difficulties in ensuring the retention and stability, diminishing the taste sensitivity, discomfort due to the large volume), cannot be ignored (Patel et al., 2018, Jablonski et al., 2015, Carlson et al., 2010)

Hard and soft tissues can be replaced with modern materials and the wide variety of artificial teeth, with varied shapes and shades, meet the aesthetic requirements of patients. But all their advantages and disadvantages must be carefully analyzed before designing the treatment strategy for complete edentulous.

The insertion into the oral cavity of a prosthetic construction of such amplitude it doesn't mean only the restoration of altered or lost functions, but it also means to achieve a new balance between all the elements of the stomatognathic system. Planning the therapeutic steps having previously informed patient consent, is fundamental for the dental treatment success (Xie et al., 2015, Sivakumar et al., 2012)

A correct prosthodontic treatment does not only means to restore the continuity of the dental arches, but it also means a holistic approach of the situation, in order to seamlessly integrate the construction into the prosthetic area. It should be taken into account that the complete edentation does not only mean the absence of teeth but also the occurrence of loco-regional imbalances, affecting all the elements of the stomatognathic system and even the appearance of general dysfunctions (Bhattacharjee et al., 2021, Mary et al., 2020)

The prosthesis aims not only to replace the missing natural dental arches but also to restore the altered functions and to limit the installed imbalances to the maximum. The application of an artificial substitute involves a relationship between two elements: the prosthesis and the biological support on which it is inserted; changes between those elements occur over time, which may impede normal functionality (Sivakumar et al., 2105) Therefore, the prosthetic treatment should not be considered completed after the application of the prostheses in to the oral cavity, but must be continued after this step, following the patient, through periodic checks, to detect and correct any changes that have occurred, both on of the biological support and on the level prosthetic construction (Kimoto et al., 2018, Müller, 2014).

Aesthetics in full denture is achieved by restoring the correct vertical occlusion dimension, the facial contours, choosing the appropriate shape, size, color of artificial teeth and artificial gingiva. In the realization of a full individualized denture, a particularly importance is played by the vestibular slope of the saddles, which must reproduce all the morphological details and to restore the physiognomic aspect by volume, relief, color (Marachlioglou et al., 2010, Bin Abdul Salim et al., 2017).

The volume of the artificial gum contributes to the rehabilitation of the appearance of the harmonious contour of the lips, to the blurring of the perioral grooves, in accordance with patient's age; it also offers the orbicularis and buccinator muscles a proper support and optimal conditions for action, in order to ensure the retention and stability of the prosthesis.

Replicating the root eminences is also important for the aesthetic aspect. These morphological elements correspond to the roots of the teeth, the most marked being the canine eminence. The prominences become progressively less marked in the premolar and molar region. Special attention must also be paid to the modeling of interdental papilla and to the free gingival margin. The color of the artificial gum must be correlated with that of the oral mucosa, but also with the skin of the patient's face.

There are different color keys capable of accurately reproducing the color variations of the natural gums, in order to create the illusion of natural.

In this article we present a clinical case that illustrates a technique for restoring the physiognomic function through an individualized aspect of the artificial gingiva of the full denture.

The polychromy method consists of the superimposition of some layers of resin, in different shades of colors in order to restore the most natural appearance of artificial gum. This technology allows to obtain physiognomically optimized full dentures, compared to the prostheses obtained through the classical technology. An aesthetic aspect as close to natural as possible will make patients to accept faster the prosthesis (Alheeti et al., 2020, Soares et al., 2016, Tarvade et al., 2015).

Complete dentures are relatively economical, easy to fabricate and repair, and provide a level of esthetics and function acceptable to many patients.

Acrylic resins remain the materials of choice for removable complete dentures, due to their indisputable qualities: easy to make and repair, good physical properties, acceptable aesthetics, good thermal conductivity, low permeability to oral fluids, color stability, low water sorption, low solubility, very accurate in reproducing surface detail, low weigh and a low cost But these materials also have a number of disadvantages, such as: poor mechanical properties, high coefficient of thermal expansion, low modulus of elasticity, increased risk of fracture, mucosal irritation caused by the release of methyl methacrylate or bacterial colonization, due to their porosity (Alla et al., 2015, Gad et al., 2017) .

Denture porosity could potentially result in increased oral biofilm accumulation and microorganisms that cause denture stomatitis. Extensive researches have been done to eliminate these disadvantages and to improve the properties of acrylic resins; these studies aimed to develop alternative materials, to modify and to optimize the structure of polymers or to increase the mechanical strength of methyl poly-methacrylate.

Frequent complaints of full denture wearers include lack of denture retention and loss of the masticatory ability. The edentulous ridge undergoes continuous resorption over the years, ultimately compromising the fit and stability of dentures. Only 13% of denture wearers seek annual dental care; dental implant supported dentures may provide more functional capacity than less costly conventional dentures, but not every patient is an implant candidate (Parvez et al., 2020, Bosînceanu et al., 2017).

Also, an important issue that specialists faced was the mucosal irritation caused by microbial adhesion to inner denture surface. Epidemiological studies report that approximately 70% of removable denture wearers suffer from denture stomatitis. Candida albicans adhesion and biofilm formation are regarded as essential prerequisites for denture stomatitis (Gendreau et al., 2011)

Another problem related to denture stomatitis is that some elderly patients present difficulties on keeping the denture clean, due to their reduced motor dexterity, memory loss, and cognitive impairment.

The classic treatment of denture stomatitis is based on topical or systemic antifungal drug,, but this infection is often persistent, since antifungal resistance has been reported in Candida albicans biofilms. The prophylaxis of dental stomatitis still represent a challenge for dentistry and more studies are needed to find the optimal prevention method (Zarco et al., 2012, Carrasco-Labra et al., 2015).

To provide antibacterial properties, in the last years more attention has directed toward the incorporation of AgNps into acrylic resins. AgNPs incorporation aims to avoid or at least to decrease the microbial colonization over dental materials, increasing oral health parameters and improving life quality.

Full dentures are not technologically difficult to make, but involve a large number of clinical and technological steps, so there is an increased risk of errors. With the development of digital technologies, subtractive and later additive methods, the working flow was considerably reduced and the precision of the prosthetic devices was greatly increased (Kattadiyil et al., 2017, Schweiger et al., 2017).

These technologies use industrially produced materials, with physical, chemical and mechanical properties superior to the conventional materials.

The main motivations for accepting or rejecting a new technology include the relative advantages they offer compared to the classical method, and these can be represented by time saving, financial advantages, and clinical benefits (Felton et al., 2016, Bonnet et al, 2017, Lo Russo et al., 2018).

The present study highlights the importance of the technologies on the characteristics of complete dentures and analyzes how modern technologies, especially digital technologies are implemented in current laboratory practice.

My contributions to this research direction can be found in the following articles:

1 **Diaconu-Popa D,** Vițalariu A, Tatarciuc M, Fratila D. Studies on the mechanical parameters of denture base acrylic resins. *Mater. Plast*. 2020; 57(4):360-365. IF=0.593.

2. Vitalariu AM, **Diaconu D**, Tatarciuc D, Aungurence O, Moisei M, Barlean- L. Effects of Surface Characteristics of the Acrylic Resins on the Bacterial Colonization. *Rev. chim. (Bucharest)* 2015; 66(10): 1720-1724. IF =0.956.

4. **Diaconu-Popa D**, Vițalariu A, Tatarciuc M. Digital technologies for complete dentures realization. *Romanian Journal of Medical and Dental Education* 2020; 9(3):43-49.

5. **Diaconu-Popa D,** Tatarciuc M, Vitalariu A. Study on the students attitude toward digital technology in dentistry. *Romanian Journal of Medical and Dental Education* 2019; 8(11): 47-55.

6. Tatarciuc M, Luchian I, Vițalariu A, Mârţu I, **Diaconu-Popa D**. Study regarding the technologies for complete dentures realization. *Romanian Journal of Oral Rehabilitation* 2021; 3(13):200-211.

7. Tanculescu O, Apostu A, Doloca A, Solomon SM, **Diaconu-Popa D**, Ciongradi CI, Vieriu R-M, Ovidiu Aungurencei O, Fatu A-M, Ioanid N, Scurtu M, Saveanu CI. Perception of Remote Learning by Fixed Prosthodontic Students at a Romanian Faculty of Dentistry. *Int. J. Environ. Res. Public Health* 2023; 20:3622. **https://doi.org/10.3390/ijerph20043622**. IF=4.614

1. ANALYSIS ON THE MAIN TECHNOLOGIES FOR COMPLETE DENTURES REALIZATIOn

Introduction

Complete edentulous therapy continues to concern specialists everywhere, being considered as a domain of particular difficulty, because it is not limited to the design and fabrication of a full denture, because it addresses to one of the most complex pathology, generating imbalances of all the elements of the dento-maxillary system.

The installation of a full edentation should be seen as the beginning of an involution process of disturbing the physiological balance, generated by the constant depreciation of the anatomical structures of the whole body, with implications on the stomatognathic system, which can trigger permanent stresses, that places the elderly, in a state of psycho-somatic lability.

An important role in the satisfaction of the patients wearing a removable denture has the realization of a prosthetic construction that adapts perfectly to the oral cavity and completely restores the altered functions; also, a balance must always be maintained between the patient's wishes and the objective possibilities of the clinical situation (Lee et al., 2019,. Hsu et al., 2020).

Making a complete denture involves a large number of clinical and technological steps, and digital methods have the advantage of greatly reducing the workflow. On the other hand, the costs of such a technological line are still very high and many technicians do not consider it an investment profitable purchase of equipment for making removable prostheses, by additive or subtractive methods.

In recent years, CAD / CAM technologies for the complete dentures realization became better known and more available, and methods and materials are becoming more efficient, allowing to obtain prosthetic constructions that satisfy the highest functional requirements. These procedures offer significant benefits to the dentist, dental technician and also to the patients (Saponaro et al., 2016, McLaughlin et al., 2019, Wulfman et al., 2020, Pacquet et al., 2019).

The present study analyzes the opinion of dental technicians regarding these modern methods of getting removable prostheses and follows the proportion in which laboratories use digital technologies.

In case of conventional technologies, for the two types of resins, heat-curing and self-curing materials, there are advantages and disadvantages.

Therefore, it is very important for the dental technician to know the particularities, advantages and disadvantages of the materials and technologies on the market, in order to choose the optimal therapeutic solution for each clinical situation.

The results of on technological possibilities of full dentures realization are illustrated by the following publications:

1. **Diaconu-Popa D**, Vițalariu A, Tatarciuc M. Digital technologies for complete dentures realization. *Romanian Journal of Medical and Dental Education* 2020; 9(3):43-49.
2. **Diaconu-Popa D**, Tatarciuc M, Vitalariu A. Study on the students attitude toward digital technology in dentistry. *Romanian Journal of Medical and Dental Education* 2019; 8(11): 47-55.
3. .Tatarciuc M, Luchian I, Vițalariu A, Mârţu I, **Diaconu-Popa D**. Study regarding the technologies for complete dentures realization. *Romanian Journal of Oral Rehabilitation* 2021; 3(13):200-211.
4. **Diana Diaconu-Popa D**, Vițalariu A, Mârțu I, LuchianI, Luca O, Tatarciuc M. Full dentures realization-conventional vs digital technologies. *Romanian Journal of Oral Rehabilitation* 2021; 13(4):160-173

Materials and methods

In order to analyze the methods used in the laboratory for making full dentures, an original questionnaire was used, with 10 questions, which was distributed to 92 technicians, aged between 24 and 49, working in private dental laboratories (table IX).

74 respondents (80.43%) completed the questionnaire and expressed their opinions on the materials used in the laboratory for making complete dentures, as well as their opinions on the effectiveness of conventional and modern methods of making these mobile prostheses.

Table IX. The questionare for the dental technicians

	Question
1.	**For the realization of full dentures, do you use in the laboratory exclusively conventional technologies?** **Yes No I don't know**
2.	**For making full dentures, do you use mainly digital technologies** **Yes No I don't know**
3.	**If you use conventional methods do you prefer HCR?** **Yes No I don't know**
4.	**If you use conventional methods do you prefer SCR?** **Yes No I don't know**
5.	**Do you think that the technology that uses SCR is superior to the one that uses HCR?** **Yes No I don't know**
6.	**Do you appreciate that complete dentures made of SCR have better longevity over time?** **Yes No I don't know**
7	**Do you think that SCR should only be used for temporary prostheses?** **Yes No I don't know**
8.	**Do you think that prostheses made by conventional methods have a better adaptation compared to total prostheses made by digital methods?** **Yes No I don't know**
9.	**Do you consider that, for complete dentures, additive digital technologies are superior to subtractive technologies?** **Yes No I don't know**
10.	**Do you think that laboratories should purchase software for making full dentures using digital methods?** **Yes No I don't know**

Results

Following the answers to the first and second questions, it is a clear the preference of dental technicians for the use of conventional methods (90.54%) of performing full dentures (fig.36).

Even though digital technologies reduce a lot the workflow, the relatively high costs of equipment and the need for additional training of technicians, make these modern methods not preferred in current practice.

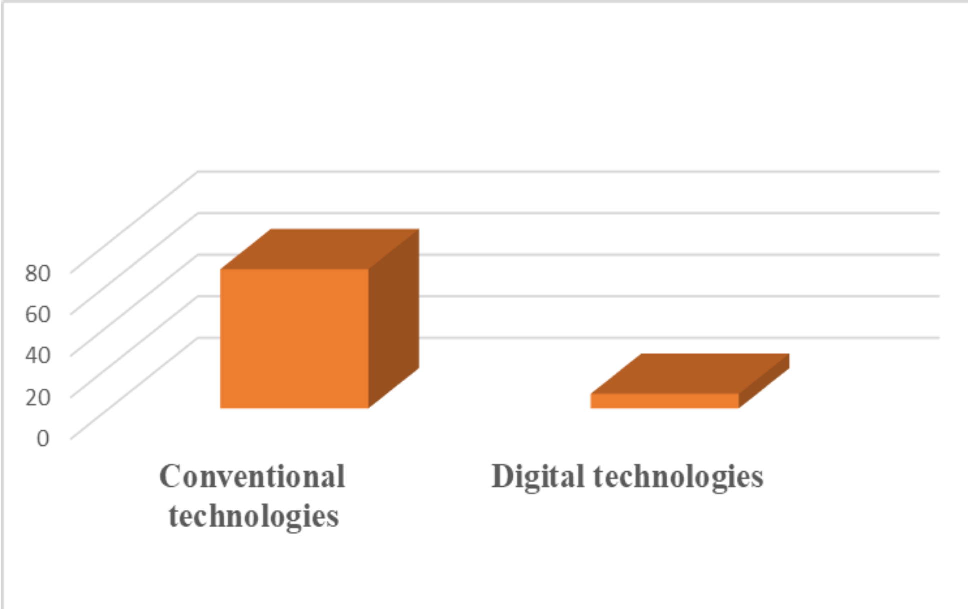


Fig. 36 Technological methods for full dentures realization

Within conventional technologies, 52 respondents (70.28%) prefer heat-curing resins for removable dentures and only 22 technicians (29.73%) use self-curing acrylic resins (fig37).

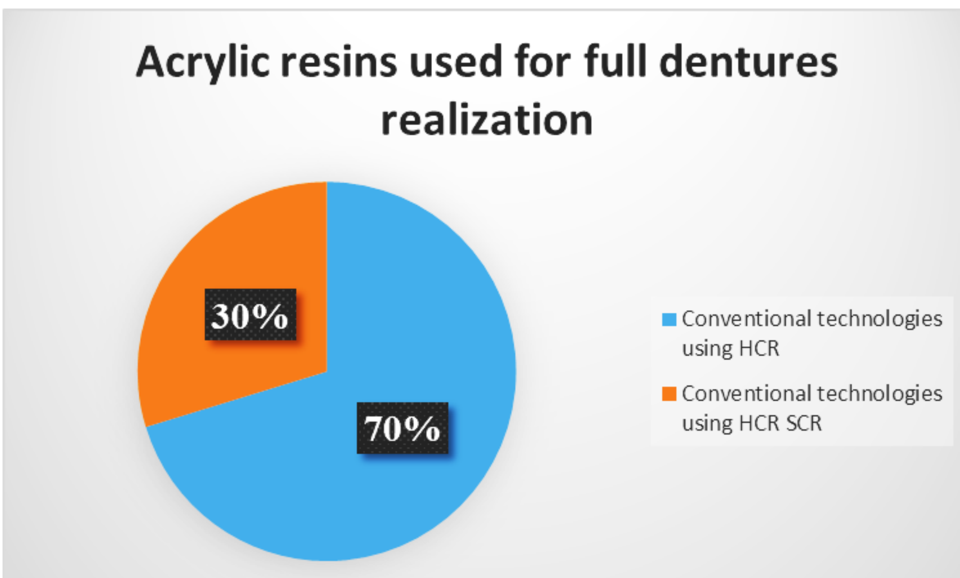


Fig.37 Acrylic resins used in conventional methods

In recent years, several types of self-curing acrylic resins have appeared, which have optimized mechanical parameters and are used in the technology of making removable prostheses. Dental technicians who answered our questionnaire consider, in proportion of 81.08% (60 respondents) that heat-curing resins are better for these type of prosthetic devices and only 18.92% (14 respondents) believe that self-curig resins are indicated for full dentures (fig.38).

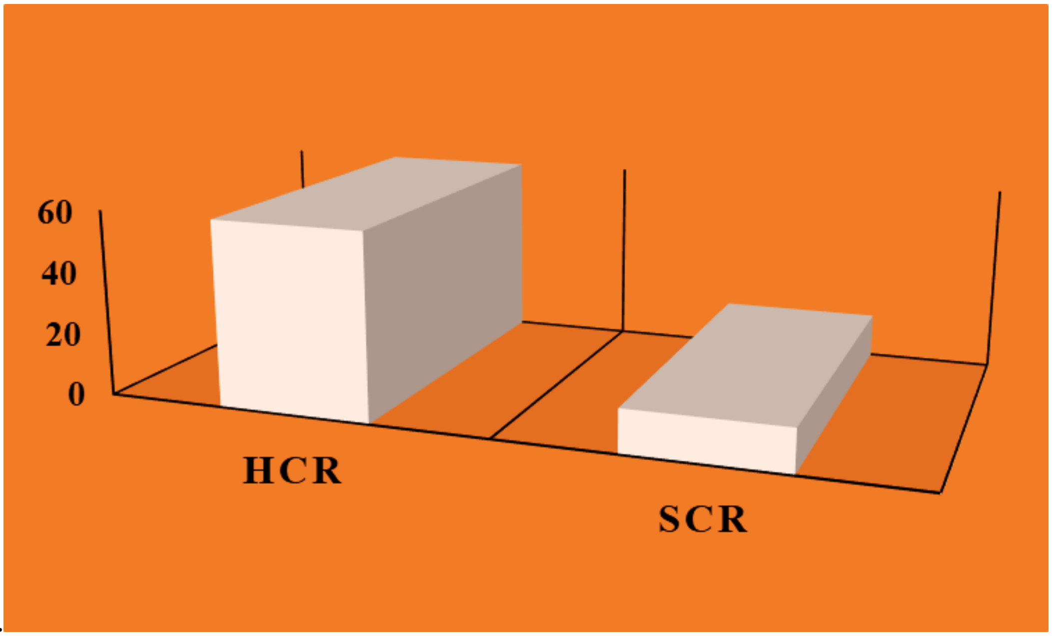


Fig.38 Opinions on use SCR utilization for full dentures realization

Only 7% of respondents (69) believe that self-curing resins have a great longevity over time compared to heat-curing resins (fig. 39)

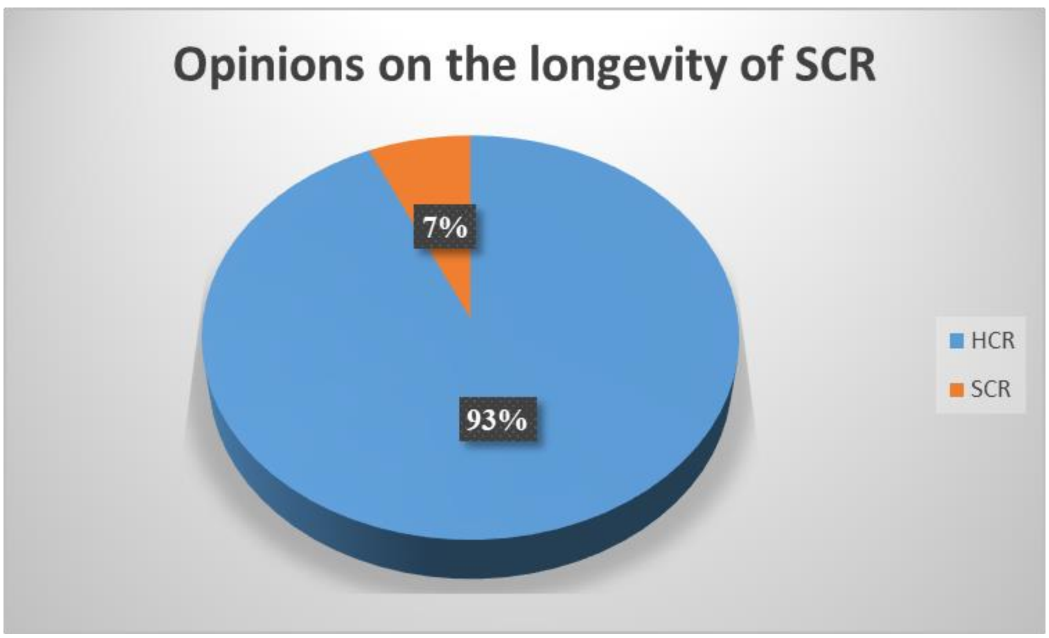


Fig.39 Longevity of self-curing and heat-curing resins

Many researchers in the dental materials field noticed that self-curing materials have a higher porosity compared to materials polymerized by other methods, therefore, recommend self-curing resins for temporary prostheses. Technicians who answered this question agreed in percent of 79.73% (59 respondents) that self-curing resins should be used exclusively for temporary restorations (fig.40).

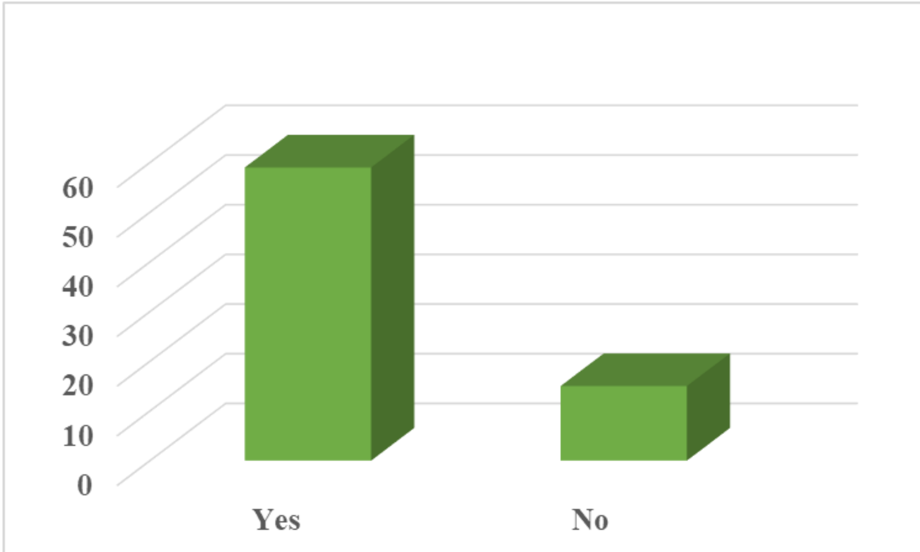


Fig.40 Opinion on the SCR utilization for temporary restoration

At present there are very few studies to compare adaptation of CAD-CAM and conventional denture. Some experts believe that digital complete dentures have a perfect marginal fit, while others say that the stability and fit of digital dentures is poor. 73% of technicians (54 respondents) state that conventional prostheses are better adapted to the prosthetic area compared to removable prostheses made by digital methods (fig 41).

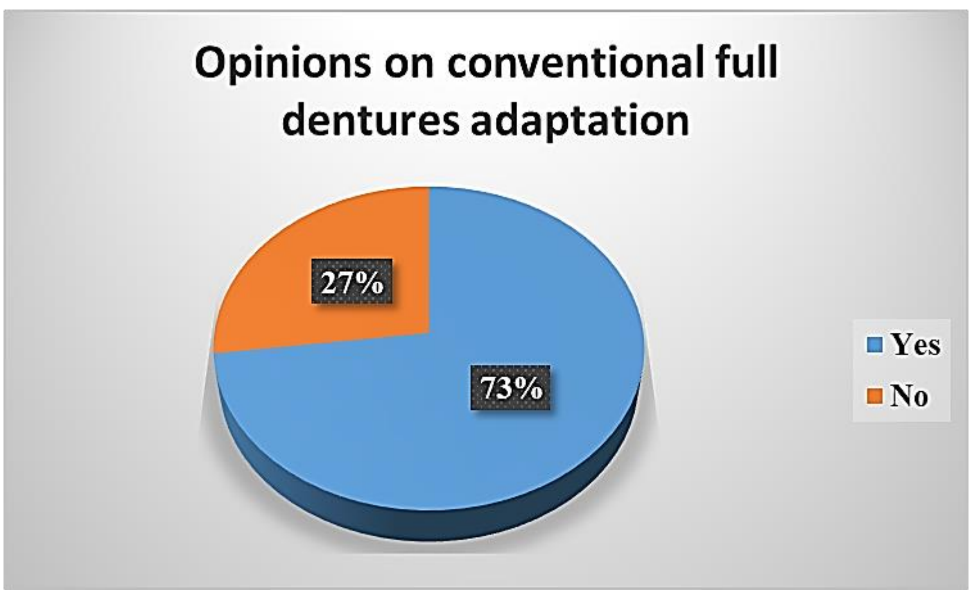


Fig. 41 Opinions on the marginal adaptation of prostheses made by conventional and digital methods

Digital technologies for removable prostheses realization can be subtractive or additive methods. Subtractive technologies involve the use of resin discs, from which, based on the information received from the CAD component, the elements of the full denture will be milled.

Additive technologies involve an superposition of the material, layer by layer, until the complete edification of the prosthesis morphology These methods allow to obtain a prosthetic construction with complex spatial geometry and very compact internal structure. The technicians who use the digital methods in the laboratory answered in this questionnaire, in proportion of 81.08% (60 respondents) that the additive methods are superior to the subtractive ones and allow to obtain more precise prostheses (fig.42).

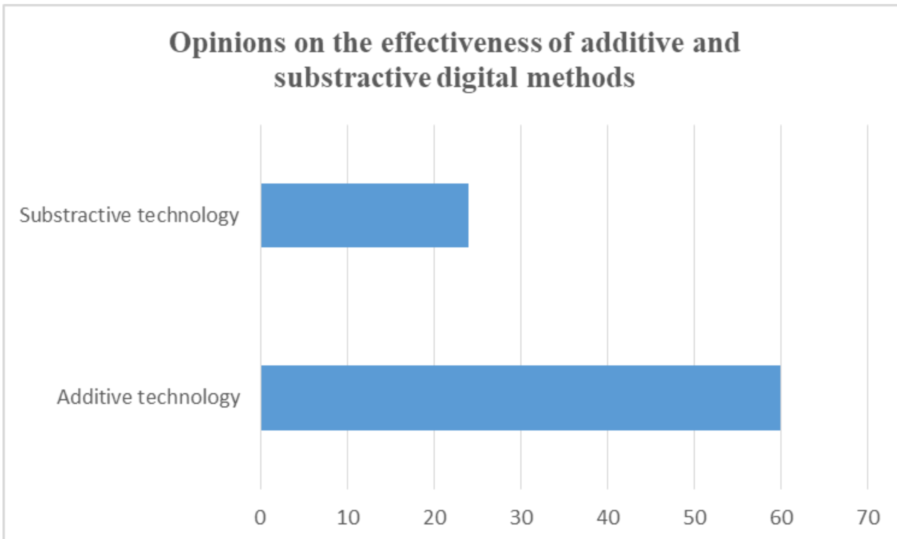


Fig. 42 Opinions on the effectiveness of additive and subtractive digital methods

57% of technicians (44 respondents) stated that, despite the advantages, it is not justified to introduce digital systems for removable full dentures realization in the dental laboratory (fig.43).

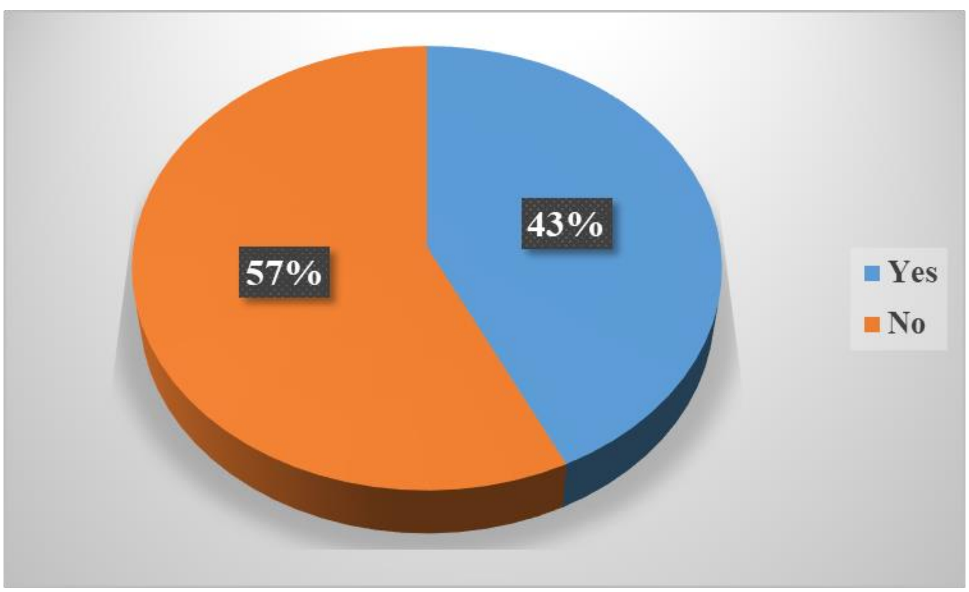


Fig.43 Opinions regarding the usefulness of acquiring CAD-CAM systems for complete denture realization

Discussions

In order to obtain removable prosthesis that satisfies all these requirements, the material has to be very carefully chosen; the resin must sum up a series of characteristics: to have a color close to the oral tissues and a translucency that allows the optimal reproduction of the physiognomic function, not to change color over time, to present volumetric stability, not to alter its shape during mechanical processing or in the oral environment, to have an elasticity and abrasion resistance adequate to any demands in the oral cavity, to be waterproof for fluids in the oral cavity, to have a smooth and glossy surface, which does not allow the adhesion of food fragments or bacterial plaque and it should be easy to clean; also the material must have a low density, a low thermal conductivity, and it must not undergo volumetric variations during temperature variations (Urban et al., 2007). The materials frequently used for partial and full dentures are acrylic resins, offering these prosthetic constructions sufficient strength and a proper aesthetic appearance (Sakaguchi, 2012).

The question that arises is whether conventional technologies remain the method of choice for making full dentures and whether digital technologies can be implemented in the case of making these prosthetic constructions. The conventional technology of full dentures realization involves a multitude of laboratory stages, during which errors can occur; a mistake during a technological step is transmitted and amplified in the next step that can eventually lead to an incorrect adaptation of the denture on the prosthetic area, incorrect occlusal repports or reduced mechanical strength. Researches had also shown that conventional acrylic resins, based on methyl polymethacrylate, in addition to the many advantages, also have a number of disadvantages (Goodacre et al., 2012, Steinmass et al., 2017, Alghazzawi et al., 2016)

Therefore, as new materials emerged and technologies evolved and diversified. Systems for injecting the resin into the mold became increasingly popular in practice, a method that has several advantages over the manual introduction of acrylate. Currently, full dentures can also be made from new generation self-curing resins, with cold polymerization, under 60 °C (Palapress, PalaXpress, Palapress Vario / Kulzer) that have comparable or even superior properties to thermopolymerizable ones: chromatic stability over time, resistance to bending, shock and elasticity. They can be molded both by pressing and injection.

Digital systems are also used to make total mobile prostheses. Computer Aided Design / Computer Aided Manufacturing (CAD-CAM) methods have the advantage of eliminating a lot of laboratory steps and reducing the cost and the risk of errors (Janeva et al., 2018, Kattadiyil et al., 2017, Wimmer et al., 2018)

In recent years, CAD / CAM technologies for the complete dentures realization became better known and more available, and methods and materials are now more efficient, allowing to obtain prosthetic constructions that satisfy the highest functional requirements. These procedures offer significant benefits to the dentist, dental technician and also to patients. CAD / CAM technologies follow three important steps: data acquisition, by using intraoral scanners or by scanning a plaster model from a conventional impression, designing the virtual prosthetic construction and digital realization of the prosthesis, using new generation materials. The resins used in digital technologies are industrially produced, have a high impact and distortion resistance, color and dimensional stability. The pre-polymerized acrylic resin is produced under high pressure and heat and no polymerization shrinkage occurs, the porosity is reduced and the microbial adhesion to the base of the prosthesis is low. The lack of polymerization contraction associated with these types of prostheses results in a very precise adaptation of the prosthesis and optimal maintenance and stability.

Not only the base of the prosthesis can be made by digital methods, but also artificial teeth, being able to obtain artificial arches with a superior morphology, strength and aesthetics. Some methods get the base, saddles and arch artificially in one step, while other technologies recommend making the base and saddles at one time and the artificial teeth at another time, and the two elements will be assembled in one subsequent step (Bidra et al., 2013).

Subtractive technologies involve the use of resin discs, and, based on the information received from the CAD component, the elements of the full denture will be milled.

Additive technologies represent another possibility of making total prostheses by computerized methods. These methods allow to obtain a prosthetic construction with complex spatial geometry and very compact internal structure (Alharbi et al., 2017).

In the manufacturing process by the additive method the prosthesis will be made by superimposing the material layer by layer, until the complete edification of the morphology. The main stages of prosthetic construction are: deposition of resin layers in the horizontal direction and their successive polymerization, in vertical orientation, removal of rods necessary to support the device during construction, removal of unpolymerized material and completion of prosthetic work. After the polymerization is completed, the prosthesis is finished and polished.

In the subsequent stage, the artificial teeth are fixed into the saddles and fixed with light-curing resin. The 3D Printing method has several advantages compared to conventional technology: superior precision, superior reproduction of details, increased work efficiency (more prostheses can be done simultaneously), less material and a shorter work-flow.

The results show that dental technicians prefer conventional technologies and heat curing acrylic resins for complete dentures, even though digital methods offer a number of advantages that make it easier for practitioners to work.

Conclusions

The differences between digital and conventional technologies are much discussed by specialists, each method having undeniable advantages, but also disadvantages.
The conventional technology, using heat curing for complete dentures was the oldest and earliest techniques; with the appearance on the market of new materials, with improved properties, the tendency is to replace these classic methods with new and more advanced production systems.

Digital technologies, initially used to make crowns and dental bridges, began to be used for removable partial and full prostheses. The main motivations for accepting or rejecting these technologies include the relative advantages they offer compared to the classical method, and these can be represented by time saving On the other hand, prostheses made by conventional methods have stood the test of time, demonstrating good mechanical behavior and satisfactory biocompatibility.

Our conclusions from this analysis are that, at least at this time, for the manufacture of complete dentures, technicians prefer conventional methods, even if the working algorithm involves a large number of clinical and technological steps, and increased risk of errors.

CAD-CAM systems still have a high price and their purchase would increase the costs of prosthetic devices, given that complete dentures are usually therapeutic solutions addressed to elderly patients or patients with limited financial possibilities. Dental technicians should consider that it is mandatory to know the stages of realization and the advantages of conventional prostheses, but, at the same time, it is necessary to know the benefits of modern technologies, in order to adapt the therapeutic solutions to the particularities of each clinical situation

2. ANALYSIS OF THE MECHANICAL PARAMETERS OF THE COMPLETE DENTURES REALIZED BY DIFFERENT POLYMERIZATION TECHNOLOGIES

Introduction

The characteristics of denture base resins play a significant role in prosthetic clinical performance and aesthetics. Some changes in denture base resin structure and different procedures for fabricating complete dentures have attempted to improve their mechanical properties. Denture base resin is often initiated by mixing the recommended proportion until a doughy mass is prepared, and the associated flask is filled, placed under pressure in a warm water bath or microwave, or the resin is allowed to be cured by chemical composition.

A lot of studies have investigated the effects of various factors on denture properties, such as commercial types of resin, their composition, filler, finishing and polishing mode (Oleiwi et al., 2018, Salih et al., 2015).

PMMA acrylic resin is the most common material used in dentistry, and is classified into heat-cured, chemical, lightcured, and microwave groups according to their chemical reactions. The polymer and monomer are mixed together and the mixture needs curing; the conventional heat-curing polymerization cycle is a long procedure (Ardelean et al, 2017).

Many studies show that heat cured denture base material exhibited higher tensile strength as compared to self-cure denture base material. Also, the rigorous non-observance of the technological parameters within this method can lead to defects, most frequently observing the appearance of porosities (Lee et al., 2019) Porosity may be due to many factors such as the presence of residual monomer, air entrapment during mixing, monomer contraction during the polymerization, monomer vaporization associated with exothermic reaction. The mean percent porosity was related to the specimens' weights and the absolute density of acrylic resin (Rickman et al., 2017, Singh et al., 2013). Many types of equipment developed for simplifying the curing procedure and to produce better properties for the cured acrylic resin.

Our study aims at a comparative analysis of the mechanical parameters of two types of resins frequently used in practice for the realization of full denture: self and heat-curing resins.

The results of the mechanical parameters of the complete dentures realized by different polymerization technologies are illustrated by the following publications:

1 **Diaconu-Popa D**, Vițalariu A, Tatarciuc M, Fratila D. Studies on the mechanical parameters of denture base acrylic resins. *Mater. Plast.* 2020; 57(4):360-365. IF=0.593.
2. Vitalariu AM, Diaconu D, Tatarciuc D, Aungurence O, Moisei M, Barlean- L. Effects of Surface Characteristics of the Acrylic Resins on the Bacterial Colonization. *Rev. chim. (Bucharest*) 2015; 66(10): 1720-1724. IF =0.956.
3. Tatarciuc M, Vitalariu V, Diaconu-Popa D. Follow up of the patients with removable partial dentures-technological aspects. *Romanian Journal of Medical and Dental Education 2019*; 8(5): 6-11

Materials and methods

Self-curing and heat-curing acrylic resins are frequently used to make full dentures. In order to analyze the mechanical behavior of these two categories of resins we used two different types of acrylic dental resins: a heat curing (Meliodent HC/ Heraeus Kulzer Senden, Germany)) and a self-curing resin (Vertex Castavaria /Vertex Dental B.V., Yeist, Netherland) We made 60 samples, 30 for each material, that were tested from the mechanical point of view and also we analized the structure and the surface parameters. Pink wax patterns were made, 2 mm thickness, with 75 mm length, 12.5 mm width at the extremities and 4 mm in thickness in the central area.

The wax patterns were transformed in acrylic specimens according to the technology used for acrylic dentures. They were invested in dental stone (Elite Rock class IV/Zhermack) in order to obtain a mold. Then the acrylic resin pastes were prepared, following the producers indications for each type. The powder and liquid were mixed into a porcelain jar, then the acrylic resin paste was packed into the mold at the dough stage, the flask was closed and pressed. For the heat-curing resin the flask was immersed into a water bath and the temperature was rised up to 100°C, at 2-4 bar, during 20 min, and for self-curing resin reaction conditions have been 45°C, 2-4 bar, during 5 min. After polymerization the samples were finished, polished and finally immersed in distilled water and stored at 37°C, for one week, before testing (fig.44).

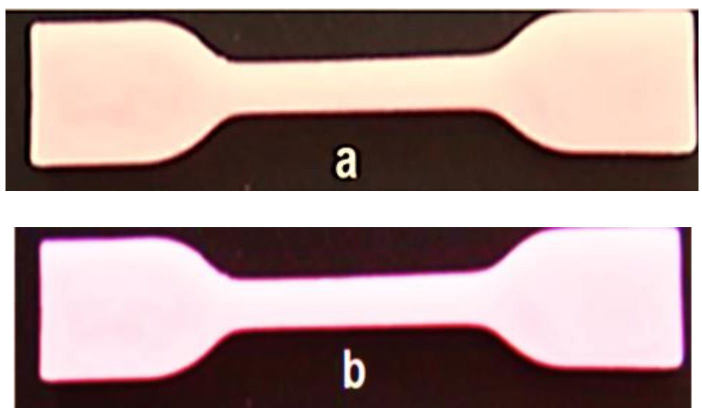


Fig.44 HCR (a) and SCR (b) samples

Tests for analyzing surface roughness

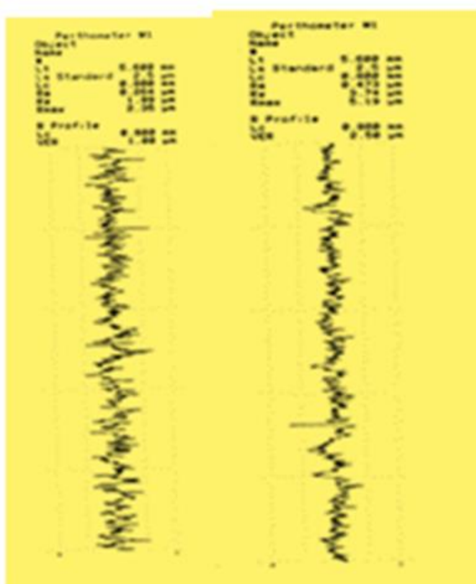
Roughness is an important characteristic of the surface quality and can be assessed by determining the micrometric profile of the finished and polished samples. For each sample Ra was registered. Ra represents the arithmetical mean of the absolute values of the profile deviations from the mean line of the roughness, and Rz - the average of all values represented by the maximum height between the maximum and the minimum profile within the assessment length, for each sample. Ra and Rz values were automatically calculated and the diagrams were recorded with the Mahr M1 Perthometer device Mechanical tests were carried out at room temperature according to the ISO 527-1: 2000 standard, using a computer-controlled testing machine (Instron 3382) equipped with a dynamic clip-on strain gauge extensometer (Instron 2620-601) for direct strain measurement. The rectangular specimens were placed and fixed between the grips of the testing machine and the tensile load was applied at a crosshead speed of 1mm/s. Young’s modulus, tensile yield stress and tensile strength were determined.

Results

The shape and dimensions of the micrometric profile have an influence on the adherence and development of the bacterial biofilm at the internal surfaces of the acrylic prostheses. After analyzing the roughness, the results do not show changes in the surfaces of the samples: HCR and SCR, the specimens being processed with the same instrumentation and in the same steps.

The charts obtained after centralization the results, for both categories of resins, are not significantly different, at this stage the roughness of the surfaces being very similar. If the finishing and polishing methods were the same, the minimum difference that appears between the two values is determined by the curing mechanism (fig.45)

HCR		SCR	
Ra	**Rz**	**Ra**	**Rz**
1.983	**11.5**	**3.374**	**16.3**



HCR SCR

Fig.45 Roughness values registered on the resin surfaces

Young's modulus (E), was calculated according to the Hook's law $E = Ϭ / ε$, as the ratio between stress (Ϭ) and deformation (ε).

At a constant pressure, the decreasing of Young's modulus demonstrates a more important deformation; the lower the Young's modulus, the greater the flexibility of the material, for total prostheses being not considered an advantage. The results were statistically processed by the method of two-way ANOVA dispersive analysis and statistical significance was set at p <0.05.

Analyzing the data obtained for the Young's modulus, calculated for both categories of resins, no significant differences were observed (fig.46).

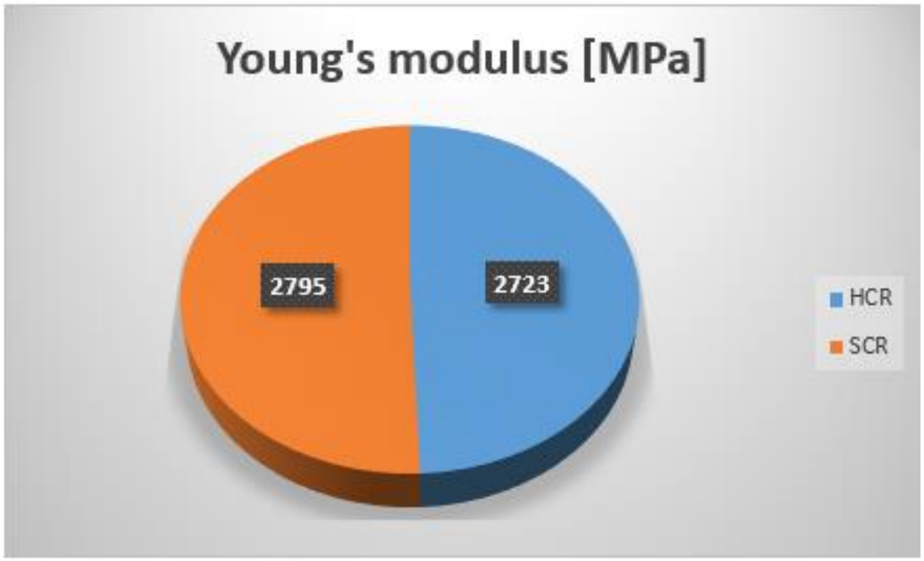


Fig.46 Young’s modulus values (MPa)

The diagrams for tensile stress and fracture strength show that, when the load is applied to the samples, it will cause changes of shape; the very first step being the elastic deformation, which is a temporary shape change, self-reversing after the force is removed.

If the action of the force continues, this change is followed by a plastic deformation and, finally by the fracture of the samples, which consists in to the separation of the material into pieces by an imposed stress (fig. 47).

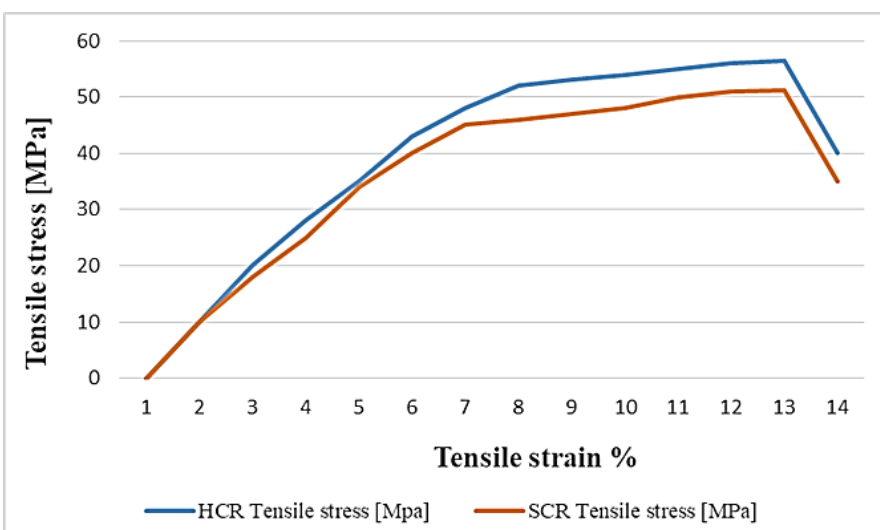


Fig. 47 Tensile tests diagrams

The maximum value for tensile stress is 44 MPa for HCR and 42 MPa for SCR (fig.48).

The ultimate tensile strength value for HCR is 56.4 MPa and for SCR is 51.2 MPa (fig.48). The very small differences between these values show that the resins have a similar behavior at tensile forces.

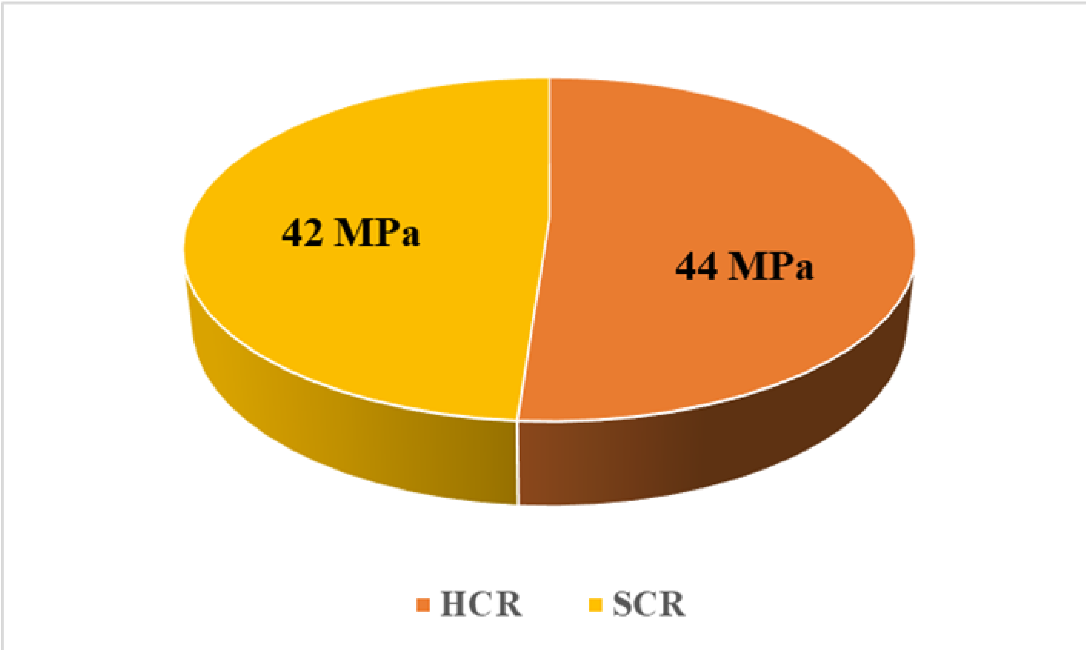


Fig.48 Maximum value for tensile stress (MPa)

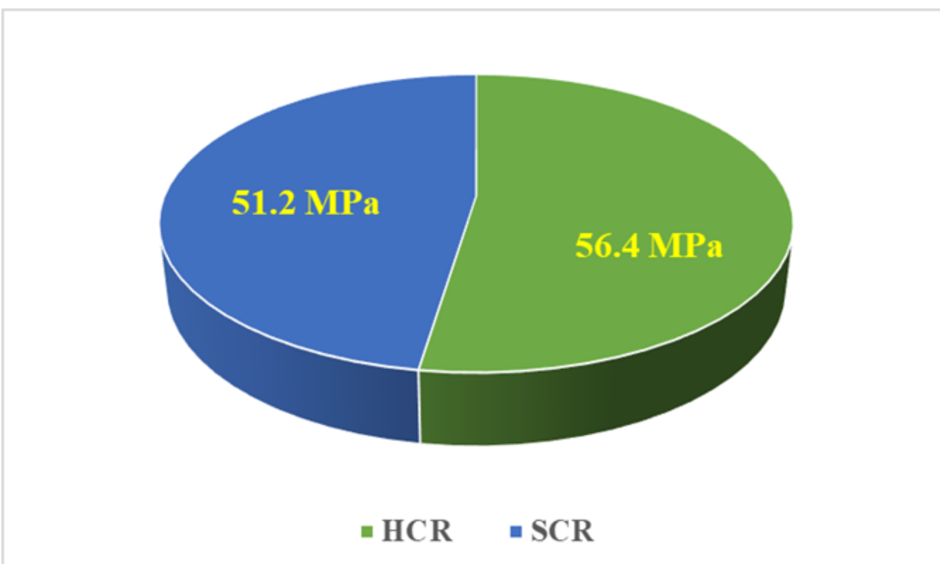


Fig. 49 Ultimate tensile strength value (MPa)

Testing the mechanical properties of the denture base resins it is an important issue. Flexural strength is useful in order to compare denture base materials because it reflects the complex stresses applied to the denture during mastication and it indicates the materials' rigidity. Since there is an A.D.A. specification designed on certain physical properties with a purpose to indicate the quality of heat-cured acrylic denture resins it is normal to employ the same tests and measurements to indicate the comparative quality of the self-cured materials designed for the same purpose.

The surface state has a major impact on the patient's comfort and the prevention of inflammation in the oral mucosa. The homogeneous structure of the material, without porosity ensures to the future prosthesis, longevity, resistance and longevity over time. Our results notice that no significant differences between the mechanical properties of the two denture base materials are registered.

Discussion

In order to obtain removable prosthesis that satisfies all the requirements, the material has to be very carefully chosen; the resin must sum up a series of characteristics: to have a color close to the oral tissues and a translucency that allows the optimal reproduction of the physiognomic function, not to change color over time, to present volumetric stability, not to alter its shape during mechanical processing or in the oral environment, to have an elasticity and abrasion resistance, adequate to any demands in the oral cavity, to be waterproof for fluids in the oral cavity, to have a smooth and glossy surface, which does not allow the adhesion of food fragments or bacterial plaque and it should be easy to clean; also the material must have a low density, a low thermal conductivity, and it must not undergo volumetric variations during temperature variations. .

The materials frequently used for partial and full dentures are acrylic resins, offering to those prosthetic constructions sufficient strength and a proper aesthetic appearance

The curing process of poly-methyl methacrylate denture determine dimensionally changes during polymerization, cooling, and finishing. The fit between denture base and mucosal tissue is important for the retention of complete denture and deformation and shrinkage affect the retention, stabilization, and support of complete denture, thus affecting patients' satisfaction (Darvell et al., 2000).

Self-curing acrylic resins are used in practice due to their easy handling and are advantageous because the monomer and the cross-linking agent diffuse strongly in the thickness of the pre-polymerized beads, this fact guaranteeing a superior fracture resistance, hardness and rigidity.

However, research shows that these materials have a less compact and less homogeneous structure, which can lead to reduced longevity of the prosthesis

The literature indicates that self-curing resins tend to be less resistant to fracture because of the larger amount of residual monomer they tend to generate (Tunaet al., 2013, Nasution et al, 2018). Some studies proved this significant differences in the fracture resistance values of self-curing and heat-curing resins (Sahin et al, 2015, Lee et al., 2018)

To overcome and compensate for such polymerization shrinkage, many studies have been performed, including denture base materials, fabrication methods, and clinical protocols such as laboratory re-mounting procedure (Faur et al., 2010, Lee CJ et al., 2010)

The results of our studies are consistent with other research in the field () and show that the polymerization method definitely influences the mechanical parameters, but also the adaptation in the oral cavity of acrylic resins full dentures. (Fenlon et al., 2010, Darvell et al., 2000, Lee et al., 2010).

The Candulor system is a more recently introduced technology that involves the use of a self-curing resin with optimized properties. This material is presented in the form of a two-component powder and liquid system and has various advantages: the resin presents a wide range of natural shades that allow the creation of a perfect aesthetic, thanks to its good fluidity it allows high reproduction of details, and last but not least, the shape and the color of the dentures are durable for years. One of the most important properties of Candulor resins is their natural gum color effect.

The special semi-opaque pigmentation of the dental resins refracts and reflects the incident light, giving the artificial gum its natural shade of pink. The powder, used for the base of the prosthesis, has excellent flow and modeling properties that make it easy to use whether the casting technique or the packing technique is used. There is a choice of different opaque shades to create a real aesthetic.

Variable proportions of powder and liquid mixture within normal limits allow flexibility in handling to be easily achieved. The powder for thedenture bases contains poly-methyl-methacrylate, benzoyl peroxide, softening agent, catalyst and pigments. The liquid contains methyl methacrylate, dimethacrylate and catalyst and should be used with care as it is a volatile liquid with a pungent odor that may irritate the skin, eyes or respiratory system.

Even if self-curing resins have been optimized over time, heat curing materials are preferred for prosthetic constructions realization because they allow an uniform diffusion of the monomer and the crosslinking agent throughout the polymer matrix during the polymerization process. This leads to a complete polymerization and uniform structure of the material, ensuring a more durable and stable denture over time. Therefore, heat-curing acrylic resins are preferred in many cases due to their superior performance and increased strength compared to self-curing resins.

The results of our studies, in agreement with other research in the field, (Consani et al, 2020, Hamanaka et al, 2016, Kawaguchi et al. 2020, Paul et al., 2018) confirm these data and recommend practitioners to use self-curing resins for temporary prostheses, or for their repairs and relinings.

In order to eliminate this inconvenience, the attention of specialists today is increasingly directed towards digital technologies, which allow obtaining more precise prosthetic devices (Alfadda et al., 2014, Cunha et al., 2013).

Computer aided design and computer aided manufacture is a very new approach that has emerged for the design and fabrication of complete dentures (Rkow, 2020). The evolution and the introduction of computer aided design and computer aided manufacturing technology into complete denturesfabrication have brought a high level of expectations as in improving the disadvantages that is associated with conventional method of complete denture fabrication in prosthodontics (Jung, et al., 2019).

When using the CAD/CAM system, special techniques are used at each stage of manufacturing a prosthetic work. The diagnosis is based on the 3D scan of the model obtained on classic impression in the dental office or following the analysis of the digital 3D scan of the oral cavity performed directly by the dentist in the office. The diagnostic data is extremely accurate, which ensures an optimal result for further design. The digitized data obtained in the diagnostic stage are loaded into the design program. The application allows the digital creation of the future prosthetic work and in this stage, all the characteristics of the future prosthetic work are established with maximum accuracy, such as the size, shape, biting contact with the opposing teeth and the material from which it will be manufactured. The CAM staep involves the of prosthetic works realization. It is an autdigital process, within which various operations can be performed: milling, finishing, polishing. The automatic control takes into account the properties of the processed materials. Processing is carried out with maximum precision.

Many studies have also compared the accuracy of bases fabricated by conventional manufacturing methods and digital methods (Infant et al., 2014, Bidra et al., 2013), because both types of technologies are used in prosthodontics. But in order to have clear conclusions, comparative analyzes are necessary, to accurately establish the advantages and disadvantages of each method

Our studies do not aim to establish which material is better or less good, but to offer practitioners a guide to choose the most suitable material for each individual clinical case.

Conclusions

Fundamentally the two types of materials are therefore quite similar in basic composition except the differences in essential ingredients. It is to be reasoned, therefore, that the self-cured resins for dentures may have physical and mechanical properties as good as, but generally no better than the heat-cured resins

Within the limitations of this study, the mechanical properties of acrylic resins were not influenced by the curing method. The acrylic specimens have similar mechanical characteristics and comparable values of surface roughness.

Also, no structural differences were found between both categories of resins. So we can notice that, at least in the initial stage, the acrylic samples of HCR and SCR do not show significant differences and have a similar mechanical behavior.

Since this research was limited to samples analyzed immediately after processing and finishing, further studies are necessary to evaluate the mechanical properties after a longer period of time, in which these materials have been functionally present in the oral cavity.

3. STUDENTS' OPINIONS REGARDING THE IMPLEMENTATION OF DIGITAL TECHNOLOGIES IN THE DIDACTIC ACTIVITY AND IN CURRENT DENTAL PRACTICE

Introduction

Digital technologies represent a strategy for the future, which had opened a new path, both in dental medicine and dental technology. These modern methods are constantly moving in new directions, to provide innovative products and systems, with the highest quality standards. With their help, perfect clinical restorations can be achieved, with high biocompatibility, no secondary reactions, excellent esthetics and a better cooperation between dentists and dental laboratories (Anadioti et al., 2020, Baba et al, 2016).

Digital technologies-Computer Aided Design-Computer Aided Manufacturing (CAD-CAM) are a new alternative to conventional prosthetics, which has revolutionized dentistry and is increasingly used and requested in recent years by both dentists and patients, due to the advantages it offers.

These systems allow obtaining optimal prosthetic constructions, with optimal biological and mechanical properties and very high precision. A great advantage of digital technologies is a shorter working time and for this reason, it is an increasingly used treatment solution, as most patients want to minimize the number of visits to the dentist's office.

The digital development in dentistry brings the need for an entirely new set of skills for dental professionals. Consequently, dental education has to increase their focus on how to educate students for these new demanding. Also, more researches on the clinical behavior and biomechanical parameters of modern dental materials will be necessary for dental professionals to increase their knowledge regarding the application of new techniques (Schweiger et al., 2018, Anadioti et al., 2018).

Conventional technologies for making dental prosthese realization tend to be replaced by these modern methods. Although dental companies have developed additional recording tools and tray systems for recording clinical information and introduced clinical protocols for them, the traditional recording protocol is acceptable. Currently, there are few studies that compare the mechanical characteristics and the particularities of the complete denture realized by these two technologies (Clark et al., 2021, Goodacre et al., 2018, Wang et al., 2020, Janeva et al., 2018).

Modern dental education needs to keep up with the constantly growing knowledge in the biomedical sciences field and involves real-life situations, interpersonal interactions with patients, practice-based learning and the gaining of clinical experience. These are the main pillars of the curricular for dental clinical disciplines aiming to improve students’ psychomotor skills and knowledge in diagnosis and treatment option and planning. In Romania, as in many other countries (Machado et al., 2020, Jiang, et al., 2021, Franc et al., 2021) during the pandemic period, concerns were raised regarding clinical internships at dental clinics (Forna et al., 2020, Iurcov et al., 2021, Goriuc et al., 2022).

Clinical training was deeply affected and each medical specialization, including fixed prosthodontics, tried to cope and to find solutions for knowledge transfer and for the compensation for the lack of clinical skills training. Learning through online systems is not completely new, this sudden paradigm shift came with the need for a rapid and sustained adaptation or both students and faculty staff (Kim et al., 2021, Vine et al., 2020).

For dental faculties in particular, this change meant the transposition of practical work, performed on real patients, into the online environment. Dentistry requires close proximity of the doctor to the patient’s mouth, during therapeutic steps that generate aerosols which are incriminated in virus spreading (Deogade et al., 2021, Epstein et al., 2021).

In this context, the dental educators scrambled to adjust an education of a practical and skill-based nature to the online environment. Though various platforms and methods are available for online teaching, many of these are of limited use or cannot be employed in the area of dental education (Chavarría-Bolaños et al., 2020, Singh et al., 2021).

Therefore, we considered it necessary to carry out a series of studies that would give us an image of the students' attitude regarding the implementation of digital technologies in current dental practice and to evaluate the perception and acceptance of remote learning among fixed prosthodontic students attending our Faculty of Dental Medicine, and to analyze the feedback regarding their experience with the new online methods, the perceived quality thereof and suggestions for improvement.. The results of the studies students' attitude regarding the implementation of digital technologies in current dental practice are illustrated by the following publications:

1.**Diaconu-Popa D,** Tatarciuc M, Vitalariu A. Study on the students attitude toward digital technology in dentistry. *Romanian Journal of Medical and Dental Education* 2019; 8(11): 47-55.

2. Tatarciuc M, Luchian I, Vițalariu A, Mârţu I, **Diaconu-Popa D**. Study regarding the technologies for complete dentures realization. *Romanian Journal of Oral Rehabilitation* 2021; 3(13):200-211

3. Tatarciuc M, Vițalariu A, Diaconu-Popa D. Digital technologies in dental laboratory. *Romanian Journal of Oral Rehabilitation* 2021; 13(2): 122-132

4. Tanculescu O, Apostu A, Doloca A, Solomon SM, **Diaconu-Popa D**, Ciongradi CI, Vieriu R-M, Ovidiu Aungurencei O, Fatu A-M, Ioanid N, Scurtu M, Saveanu CI. Perception of Remote Learning by Fixed Prosthodontic Students at a Romanian Faculty of Dentistry. *Int. J. Environ. Res. Public Health* 2023; 20:3622. https://doi.org/10.3390/ijerph20043622. IF=4.614

Material and method

The study on thje evaluation of the students' attitude regarding the implementation of digital technologies in current dental practice a included 123 students from the Faculty of Dental Medicine, Dental Technical Specialization, 61 on the second year and 62 on the third year
The students were asked to specify the year of study and their age. An original questionnaire was used, with 10 questions, in order to analyze the students' knowledge and attitude regarding the use of digital technology in dentistry and, in particular, in the dental laboratories. (Table XI).

The participation in the study was voluntary. The subjects were informed about the study, the content of the questionnaire and signed the informed consent. The questionnaires were filled anonymously, in order to protect the subjects' intimacy and to obtain objective answers as much as possible.

For the evaluation on the perception and acceptance of remote learning among dental students an observational cross-sectional, questionnaire-based online survey regarding the remote learning system in use during the COVID-19 pandemic was conducted during 16 December and 23 December 2020. The study focused on students that were supposed to undergo clinical training at a fixed prosthodontics clinic, but the pandemic context drastically limited direct contact between them, the patients and all other persons involved in the educational process.

These were students in the third, the fourth and the sixth year of study at the Romanian section of the Faculty of Dental Medicine at the Grigore T. Popa University of Medicine and Pharmacy Iasi. The questionnaire was created in Romanian and was setup using Google Forms (Mountain View, CA, USA, Alphabet). Misleading questions, multiple negations or unclear formulations were completely avoided.

The questionnaire was reviewed for face validity by three experts in dental medical education in order to identify relevant key issues for dental medical students and to assess its relevance and accuracy. Additionally, the study was validated in a pilot study on 32 students. Their feedback and suggestions were used for improvement of the survey. None of these students participated in the final study.

Table XI. The questionnaire for the 2nd and 3rd year dental students

1. Do you work or practice in a dental laboratory? **Yes (period) No**
2. Do you have any knowledge on CAD-CAM technology? **Yes No**
3. What materials can be processed using CAD-CAM technology? **a. ceramic b. polymers c. alloys / metals**
4. What types of prostheses can be made using CAD-CAM technology? **a. fixed prostheses b. partial dentures c. full dentures**
5. What materials can be processed using 3D Printing technology? **a. ceramic b. polymers c.alloys/metals**
6. What types of prostheses can be made using 3D Printing technology? **a. fixed prostheses b. partial dentures c. full dentures**
7. Do you consider useful to introduce digital technology into the dental technology? **Yes No**
8. Do you consider these digital methods to help the dental technician? **Yes No**
9. Do you think digital technologies will replace the dental technician in the future? **Yes No**
10. Do you think that the widespread implementation of digital technologies would have a negative impact on the number of employees in dental laboratories? **Yes No**

The invitation to participate in the survey and the link to the Google Forms informed consent and questionnaire documents were posted online in Microsoft Teams, in all three teams corresponding to the involved clinical years, for all 488 Romanian students.

The representative sample size for the total number of third, fourth and sixth-year students (n = 488) was calculated for a confidence level of p = 95%, z = 1.96, and margin of error of 5%. The resulting calculated sample size was 216. Six hundred fifty students were enrolled in the clinical training years (third to sixth year). For the same confidence level (p = 95%) and margin of error (5%) the calculated sample size was 242. The questionnaire was answered by 259 students, representing 53% of the total number for the three targeted years. The sample was also representative for all clinical training years. Participant sampling was volunteer based, and no incentives were used for study participation. All respondents delivered answers to all questions in the questionnaire, making the acquired data valid and usable as provided. No data were eliminated. The questionnaire focused on students' perceptions and feedback on didactic activities during pandemic period and was structured into three parts. The first part included single and multiple-choice general questions regarding remote learning and its impact (Q1–Q12). The second part also included multiple-choice questions related to the perceived quality of remote teaching, learning and assessment in the fixed prosthodontics disciplines for both theoretical knowledge and practical skills (Q13–Q20). Finally, the third part included two open questions, asking for suggestions to improve didactic activity for fixed prosthodontics disciplines and also for free comments on this subject. The first eight questions (Q1–Q8) had answers rated on a five-point Likert scale, representing ordinal variables, with different constructions of the answers, and each question was attached to the response scale with the corresponding coding. The response categories for these questions are presented in table XII. The lower the score, the stronger is thenegative perception of the student and the higher the score, the stronger is the positive students' perceptions and acceptance of remote learning and its consequences. The questions 9–20 (Q9–Q20) were purely nominal, with no ranking of the possible answers, while the remaining two were open-ended questions (Q21, Q22). Data analysis was carried out using IBM SPSS Statistics, version 28 (IBM, Armonk, NY, USA). Statistical significance was set at p = 0.05.

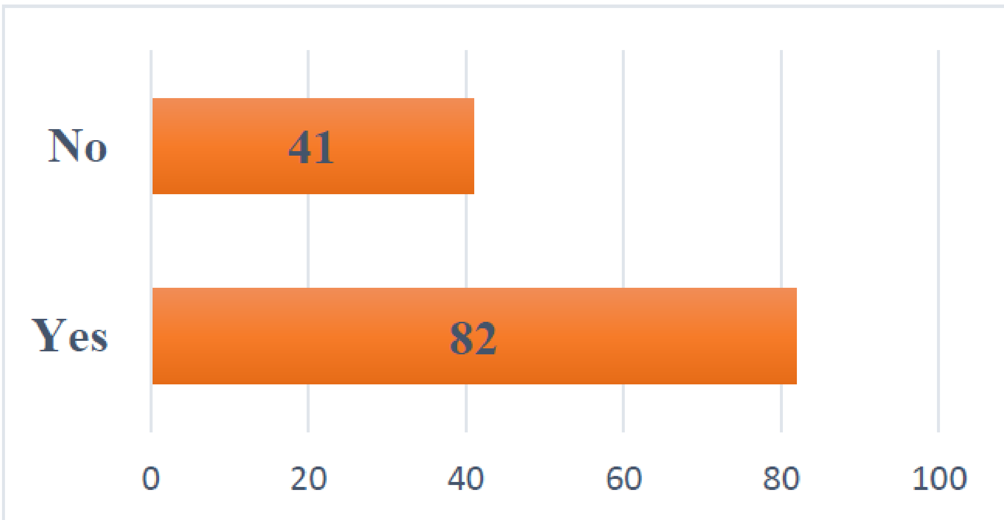
Table XII. Evaluation on the perception and acceptance of remote learning among dental students.

Questions	Answers Rank				
	1	2	3	4	5
Q1. What do you think about online education?	very bad	bad	neutral	good	very good
Q2. How efficient is online education for you?	not at all	a little bit	medium	a lot	very much
Q3. Do you enjoy learning online?	not at all	not really	neutral	yes, but with some changes	yes, definitely
Q4. To what extent did the relationship with colleagues suffer?	very much	a lot	moderate	a little bit	not at all
Q5. To what extent has the relationship with the teaching staff suffered?	very much	a lot	moderate	a little bit	not at all
Q6. To what extent do you receive help from teachers during your online study?	very much	a lot	moderate	a little bit	not at all
Q7. To what extent have the changes in the last 10 months affected you psychologically?	very much	a lot	moderate	a little bit	not at all
Q8. In your opinion, after the end of the pandemic period, should online teaching remain a component of dental education?	no	to little extent	moderate extent	to a large extent	yes

Results

The repondents' age was between 18 and 29 years, with an average of 20 years for the second year (30 students) and an average of 21 years for the third year (34 students).

After analyzing the answers it was found that out of the total of 123 students, 82 work already into a dental laboratory (fig. 65) between one month and one year (students of the second year), and for a period between 2 months and 2 years (for third year students) (fig.50).



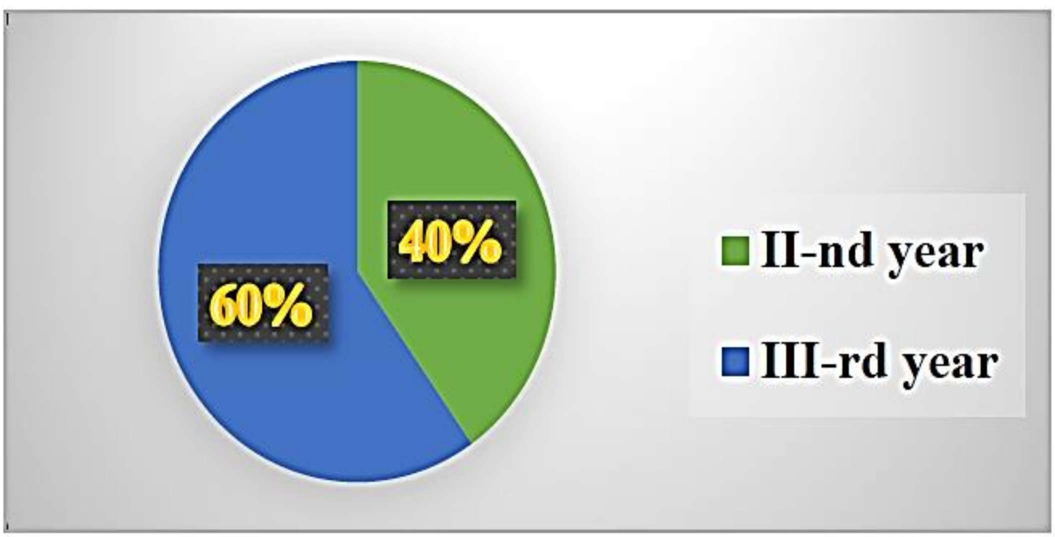


Fig. 50 The number and distribution of students who practice or work in the dental laboratories

The work experience into the dental technique laboratory offers the students an image on the difficulties of making certain dental prostheses and on the particularities of the different technologies.

Students who have done more practice in laboratories equipped with high-performance devices are aware of digital technologies and realize the advantages of these methods.

In our study, all respondents, (100%), said they had knowledge about digital CAD-CAM subtractive technology, but a small number knew all the materials that can be used to make dental prostheses ussing this method (fig.51.a, fig.51.b).

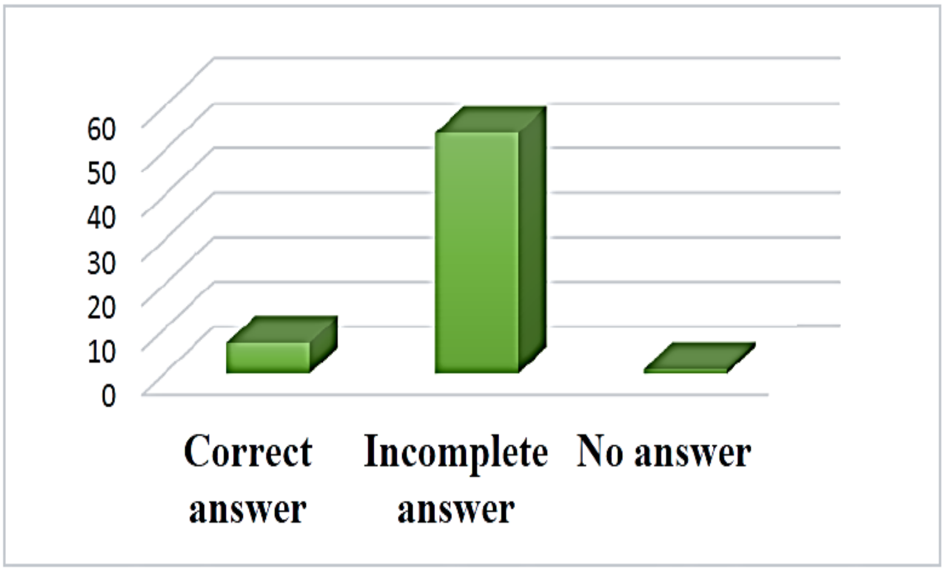


Fig.51 a Second year students'answers regarding the materials that can be used in CAD-CAM technologies

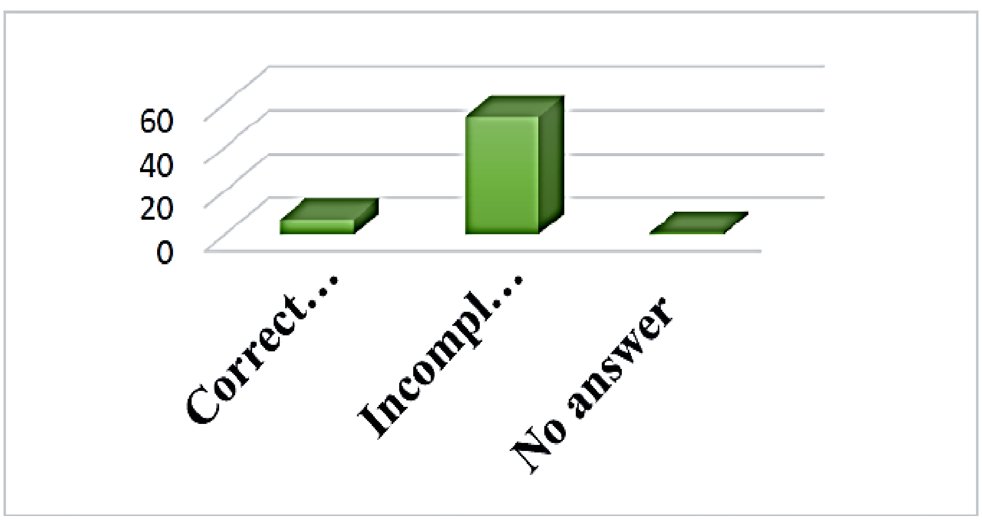


Fig.51 b Third year students'answers regarding the materials that can be used in CAD-CAM technologies

The limited experience of students in the laboratory does not give them an overview of the materials and working methods used in digital technologies.

The differences between the answers of the second year and the third year students are insignificant, which shows that they focus during the practice period on the accumulation of practical knowledge on the techniques used in the laboratories where they work and focus less on the accumulation of information on new technologies that appear or are used in the field of dental technology.

The answers for the question nr.4 show that a small number of students know all types of prostheses that can be made using CAD-CAM subtractive technology (fig.52.a, fig.52b).

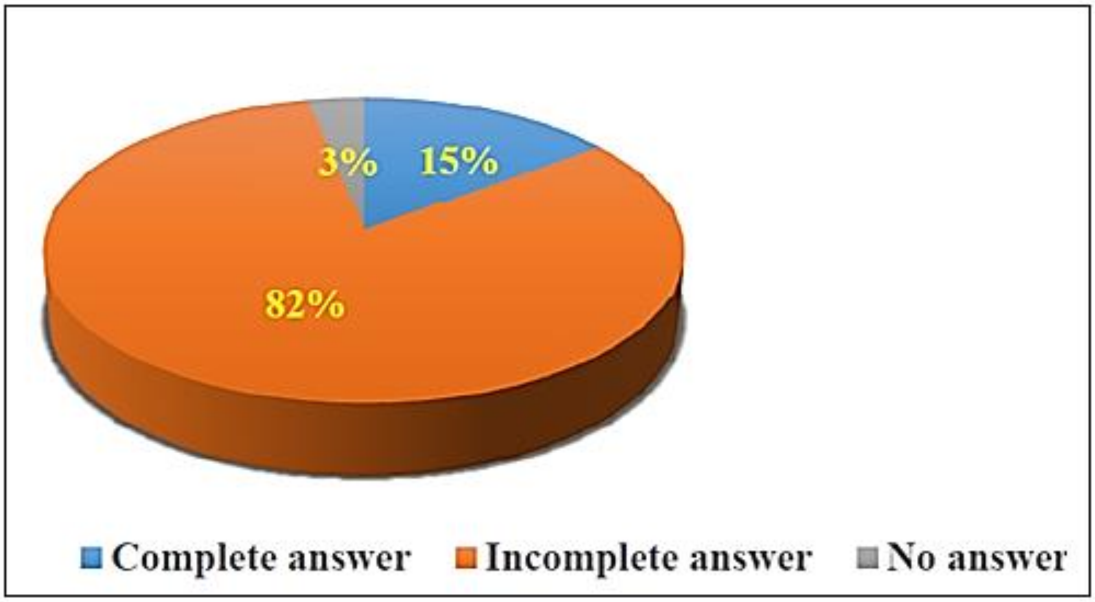


Fig.52 a. Answers of the second year students regarding the types of prostheses that can be realized by CAD-CAM technologies

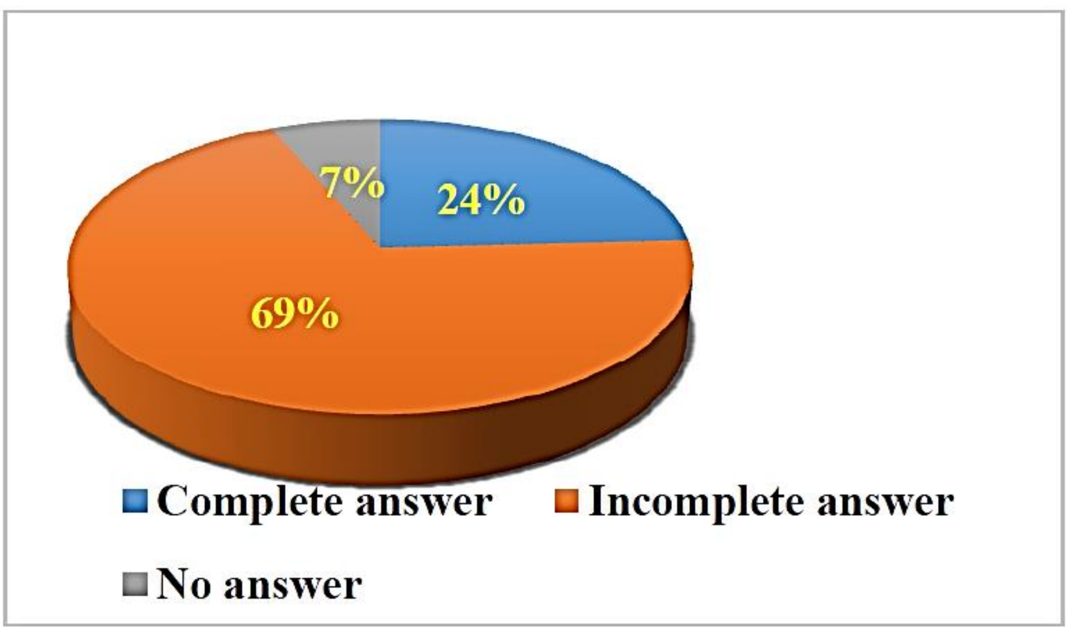


Fig.52 b Answers of the third year students regarding the types of prostheses that can be realized by CAD-CAM technologies

As for 3D Printing technology, students partially knew the categories of materials used to make dental prostheses using this method (fig.53, fig.54).

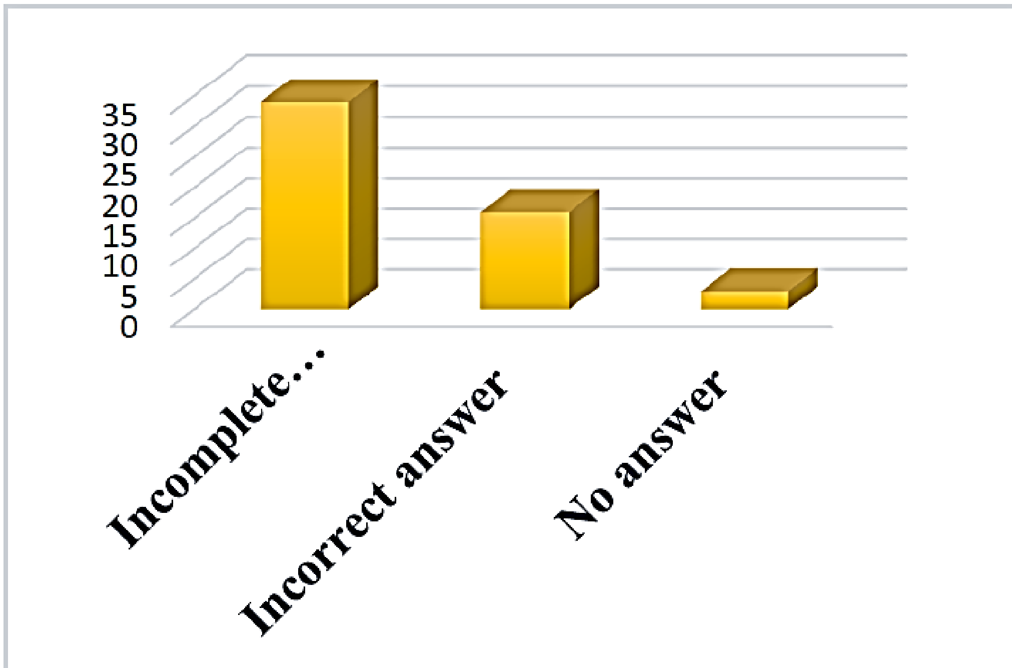


Fig. 53 Answers of the students of the second year regarding the materials that can be used in 3D Printing technologies

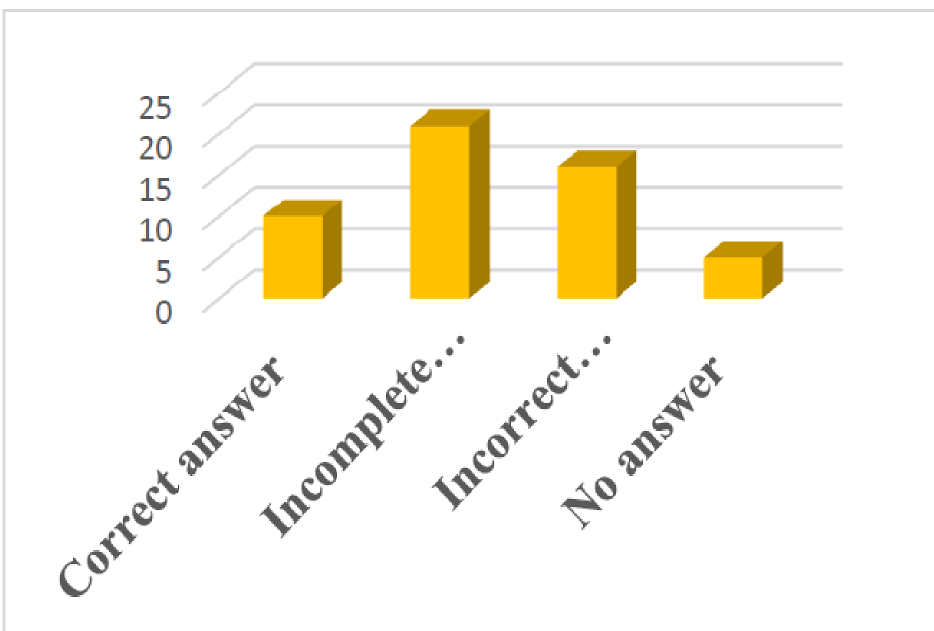


Fig. 54 Answers of the students of the third year regarding the materials that can be used in 3D Printing technologies

Even regarding the types of prostheses made by 3D Printing technology the students of the two years of studies do not have complete knowledge (fig.55 a, fig. 55 b).

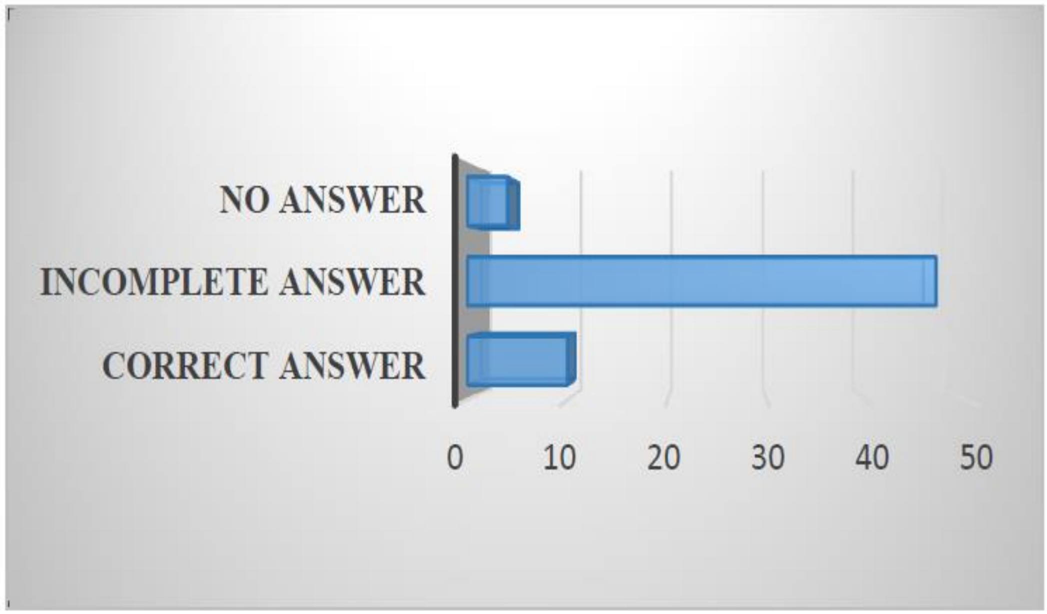


Fig. 55 aThe answers of the students of the second year regarding the types of prosthese that can be realized by 3D Printing technologies

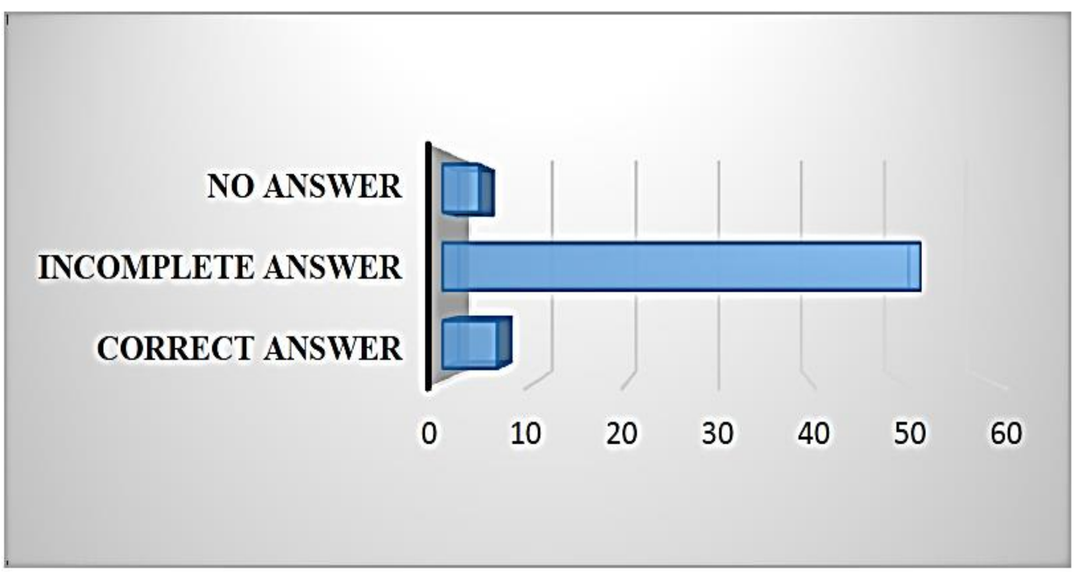


Fig. 55 b Answers of the students of the third year regarding the types of prosthese that can be realized by 3D Printing technologies

3D printing technologies are even more recently introduced in practice, and for mobile, partial and complete dentures hey are still little used; therefore, students' knowledge of these methods is even lower.

Of the 123 respondents, 120 (97%) noticed that it useful to introduce the digital technology in the current laboratory practice (59 from the second year and 61 from the third year), two students replied that the implementation of these methods is useless (2%) and one student did not answer the question (1%) (fig.56)

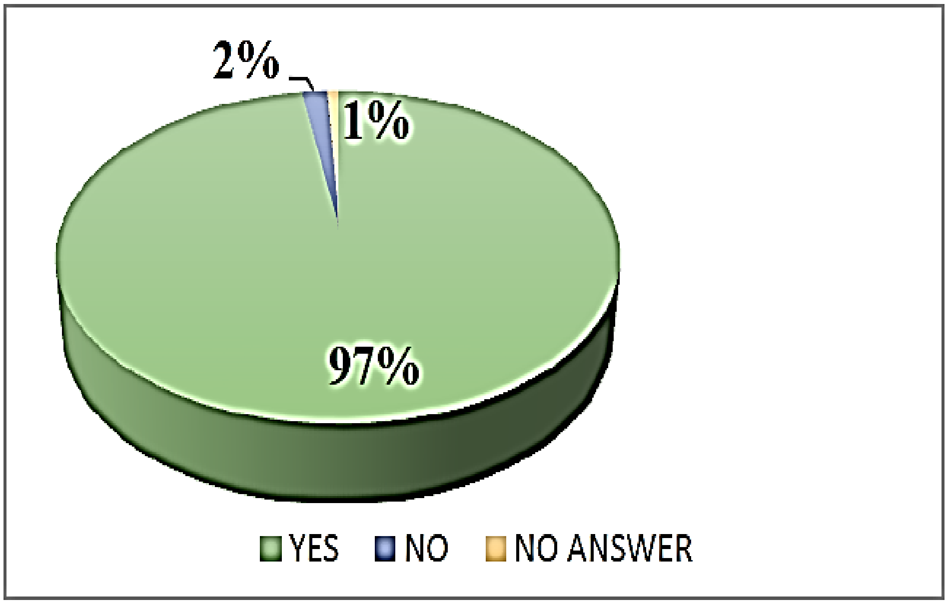


Fig. 56 Student answers regarding the usefulness of introducing digital technologies in laboratory practice

111 students (90%) considered that digital technologies are a real help in the dental technician's activity, and 12 respondents (10%) do not found these methods useful (fig.57).

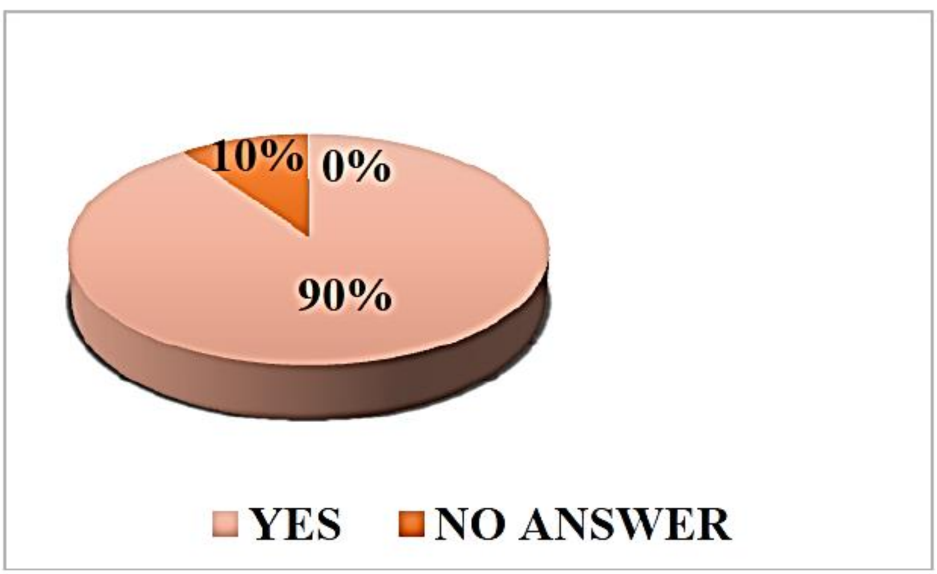


Fig. 57 Student answers regarding the efficiency of the laboratory activity by applying digital technologies

Thirtyfive respondents (28%) considered that digital technologies will replace the dental technicians in the future, and 82 (67%) did not consider these alternatives a threat to the technicians. Six students (5%) did not answer that question (fig. 58).

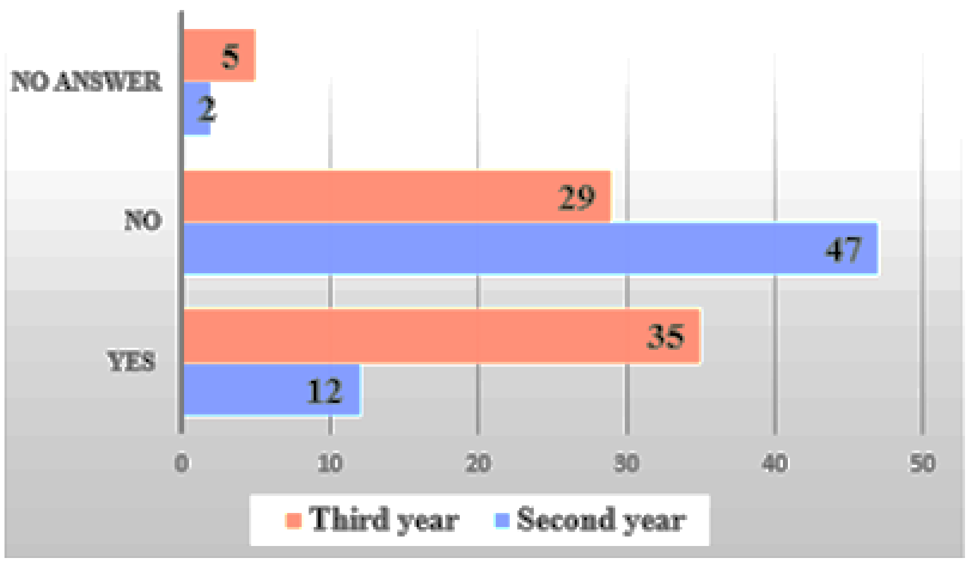
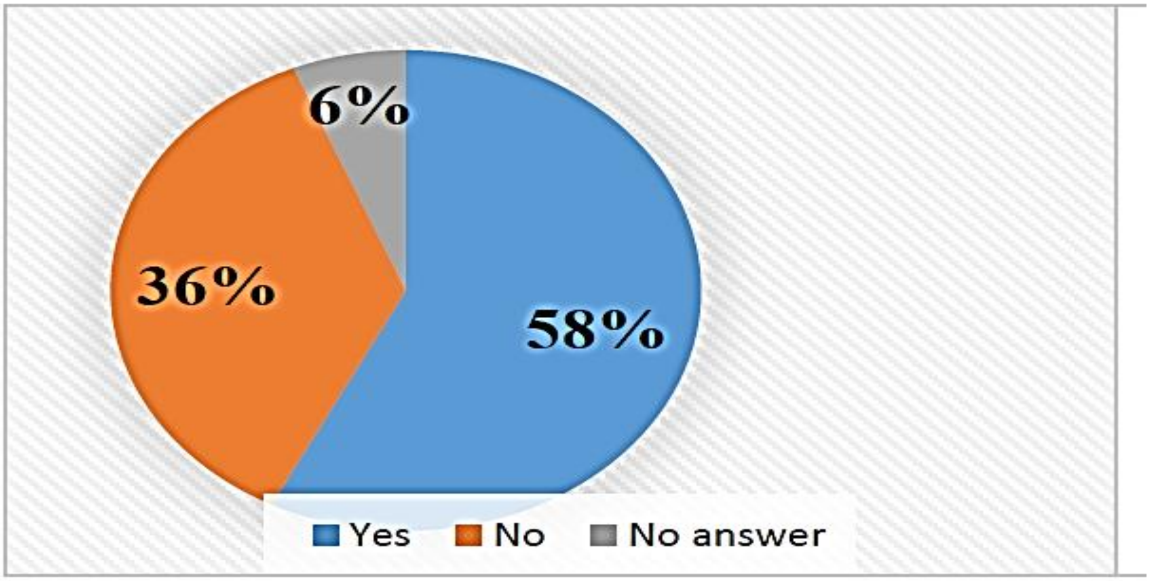


Fig.58 Opinions regarding the future replacement of dental technicians as a result of the implementation of digital technologies

Although it is useful to introduce digital technology into mainstream practice, 65 (58%) students felt that these methods would have a negative impact on the jobs in dental laboratories, 41 (36%) said that the techniques will not affect the jobs for technicians and 6 (6%) did not answer this question (fig.59).

Due to the reduction in the number of steps and working time, students are convinced that the number of jobs will be declining after the widespread implementation of digital methods in the dental laboratory



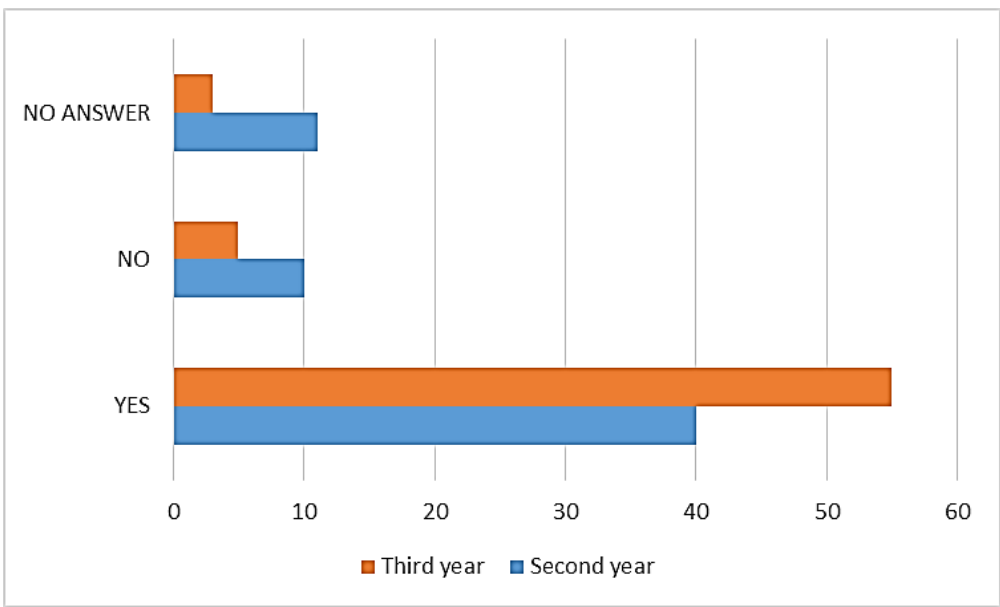


Fig. 59 Opinions regarding the future impact on dental technicians jobs as a result of the implementation of digital technologies

Analyzing the results it was found that 97% of the respondents answered that digital technologies are useful for most aspects of dental practice, due to the significant reduction of the working stages, because increase sharing of patient information, reduce the appointments, reestablish the risk of occurrence of errors and decrease material losses.

Obstacles that impede the acceptance of digital technologies include cost, lack of comfort with technology, software incompatibility, practice guides still unclear.

Following the reduction of the number of laboratory steps and the digitalization of the process of obtaining dental devices, 36% of the students believe that these methods will have as result the decrease of the number of jobs for dental technicians.

Although most students practice in dental laboratories, and absolutely everyone knows theoretically the digital technologies -CAD-CAM and 3D Printing-, just a small percentage (10%) know all the materials used in these technologies; also, 15% of second year students and 24% of third year students know all types of prostheses that can be obtained by these methods. Regarding student Perception and Feedback on Remote Learning and Its Impact, the compilation of the questions and their internal consistency (Q1–Q8) was tested and the reliability for each latent variable used in this study was confirmed by Cronbach's alpha test ($\alpha = 0.829$). The first three questions are related to the students' general opinion about online education (Q1), their perception about its efficiency (Q2) and the pleasure of learning online (Q3). One hundred four students (40.15%) have a good or a very good opinion about online education (Q1), while 99 (38.22%) are neutral and 56 (21.62%) have a bad or very bad opinion about online learning. Regarding the efficiency (Q2), only 74 (28.57%) found online learning to be efficient, while 89 (34.36%) found it efficient or very efficient. Of the students, 45.95% (119) enjoy online learning, while 36.64% (95) do not enjoy it (Q3) (fig 60). Pearson's chi-squared tests showed a strong correlation between the three items (Q1, Q2 and Q3) ($p < 0.001$)

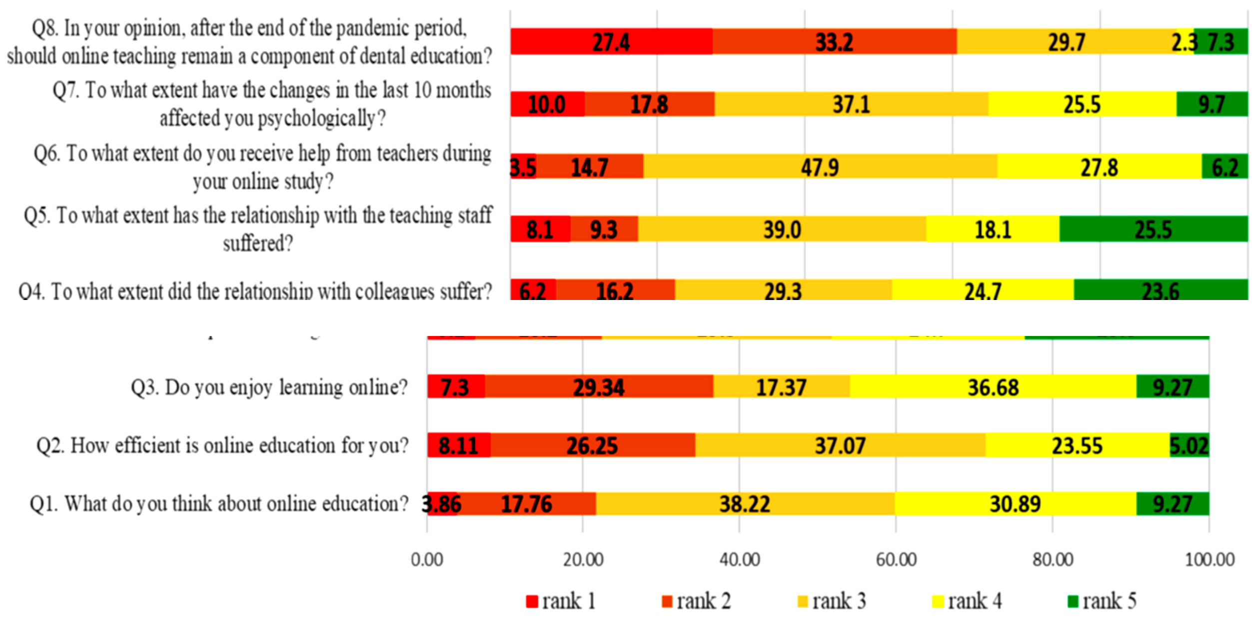


Fig.60 Distribution of relative frequencies of answers to questions one to three (Q1–Q8). The numbers in the bars indicate the percentages of the answers received (n = 259).

Fifty-eight (22.4%) participants stated that their relationship with their colleagues suffered considerably, a percentage to which we add those who felt a moderate alteration of their relationship (29.3%) (Q4). It seems that not only the relations with colleagues have suffered but also those with the teaching staff (Q5). Fifty-six, 4% of the participants in the study claimed that this type of relationship suffered, from a moderate to an extreme intensity, especially in the conditions in which 17.4% of students perceived the support that they received from their teacher to be absent or very reduce (Q6). However, at the same time, the vast majority (81.9%) of students regard the help from teaching staff as moderate to extremely helpful. Of the students, 35.2% were not psychologically affected at all or only slightly affected, while 37.1% perceived moderate psychological changes (Q7). Having the experience of all types of learning exclusively onsite, exclusively online and hybrid— 62% of the respondents believe that online education should not exist, or just to a small extent, a result justified by the practical nature of the profession and by the university profile (Q8) Q9 focused on the possible motivations for enjoying online/remote learning. The respondents were pleasantly surprised primarily by the high degree of flexibility offered by this type of education (63.6%), its ease of use (48.2%) and the accessibility of platforms, materials and resources (45.1%).

More than half of the students (56.4%) found the quality of the presentation to be the main instrument to increase student involvement during online/remote activities (Q11). The clinical and practical training component of the discipline is another factor which motivates the students to stay involved and focused (49%), followed by the quality of the information itself (44%) and an increase in the level of interaction between the students and the teacher (41.3%)

Regarding the preference for teaching theoretical notions—online, onsite or hybrid (Q13)—the respondents have equally divided opinions between hybrid and online. In the case of the online version, they prefer an increased share of activities carried out synchronously, with real-time interaction with the teaching staff. In their opinion, the teacher should personally present the course and thus reduce the need to watch recordings or video demonstrations with pre-recorded explanations (Q14) (60.23%). According to the students, the best way to facilitate the assimilation of the transmitted practical and theoretical notions (Q19) is through discussions and debates based on clinical situations (61.00%). Regarding the most popular method of examination/evaluation for disciplines with a practical component (Q20), students would prefer onsite examination (58.3%), with the performing of practical maneuvers (52.51%) and, in smaller proportion, the simple andmultiple choices tests (31.27%), or use of virtual patients (29.34%).

Discussions

The benefits of CAD CAM systems are represented by maximum precision for all results combined with easy handling, the registration of a digital impression and ordering quickly and easily the restoration online, material versatility, extremely wide range of applications (Güth et al., 2017, Boujoual et al., 2018).

Thanks to CAD-CAM technologies, perfect clinical restorations can be achieved, with optimal mechanical and biological parameters and with excellent aesthetic appearance (Jeremias et al., 2017).

In addition to the many known advantages, the respondents are also informed about the disadvantages of these systems, namely the possibility to perform only small prosthetic devices in the dental office, the high price of equipment and materials and the higher costs of prosthetic works. Indeed, the initial cost of equipment and software is still very high, and practitioners who are unable to achieve a sufficient volume of restorations will need a long time to recover the investment.

An important goal includes reducing unit cost and making affordable restorations and appliances that otherwise would have been prohibitively expensive. However, to date, chairside CAD/CAM often involves extra time on the part of the dentist, and the fee is often at least two times higher than for conventional restorative treatments using lab services (Marinello et al., 2017).

With all this knowledge, dentists will be more informed about the evolution of modern technologies and will look for ways to equip their dental offices with this modern systems. But, only by analyzing the advantages and disadvantages, knowing the technologies very well, having information about the characteristics of the materials and balancing the investments and benefits, the practitioners will be able to make the best decision for their current practical activity (Janeva et al., 2018, Alghazzawi et al., 2017).

Clinical studies on the use of digital technologies have shown that functional recovery is superior and patient satisfaction is higher when using computerized systems. However, it is still necessary to further train the dental team in terms of optimal design of prosthetic restorations and choosing the best method of making a prosthesis, depending on the particularities of the prosthetic area. Both the dentist and the dental technician must know the advantages and disadvantages of conventional methods, but, at the same time, it is necessary to know the benefits of modern technologies, in order to adapt the therapeutic solutions to the particularities of each clinical situation. Our study emphasizes once again the need to familiarize specialists, since the training period, with these technologies of great future,

The type of teaching (hybrid/online/onsite) of the theoretical notions in relation to the content type was another evaluated issue. The outcome underlines the preference for online or hybrid teaching, with the distinction between the two being decided by the type of content—synchronous or asynchronous. The correlation between the two variables is a significant one. This is somehow expected because synchronous content requires real-time interaction with the teaching staff, while asynchronous content can be delivered fully online, without the instant supervision of an educator (Varvara et al., 2021, Alharbi et al., 2022). Overall, the students were more favorable to direct interaction with the professor, as it provides an opportunity to ask questions in real time and to get instant feedback (Prakash et al., 2017). In analyzing the online teaching of theoretical notions, the respondents identified two main possible ways of ensuring higher quality: using video demonstrations of diagnostic and treatment methods and including a higher proportion of clinical cases in the delivered presentations.

These measures could, at least partly, compensate for the reduced level of interaction between the students and the educators and patients in the online environment. Regarding the asynchronous teaching/learning, due to technological advancements and several undeniable benefits, dental podcasts have become popular among students and practitioners as tools for learning and for updating knowledge in general.

Some studies (Zhang et al., 2022) have shown that, in comparison with text book reading, watching video podcasts is a more efficient learning method, an efficiency that is reflected by higher scores in MCQ tests. Short-duration podcasts in particular (Prakash et al 2017) were perceived by students as use full supplementary learning tools that aided them for revision and in their preparation for assessments. An in-depth analysis of the importance of podcasts in learning in the medical field was undertaken by (Bentata et al., 2020).

Regarding the teaching of practical skills, the general opinion is that this should be undertaken more on real patients and be less reliant on the use of video demonstrations and virtual patients. This is again linked to the fact that dentistry is regarded as a practical domain that should deliver education in a very practical way and in a setting that is as close as possible to a real clinical environment. Other alternatives are regarded as moving away from the normal path that education should progress on and could be accepted only because of the exceptional situation generated by the COVID-19 pandemic.

Though there is no replacement for hands-on clinical experience, versatile and immersive learning experiences can be obtained through haptic technologies and virtual (Moog Simodent) and augmented reality (DentSim, CDS-100, IRIS) (Huang et al., 2018). These have the potential to deliver relevant, flexible, and immersive learning experiences if they are further enhanced according to the needs of dentistry. At the same time, they should be portable and affordable for large-scale usage by students (Witze et al., 2020, Chavarría-Bolaños et al., 2020, Elangovan et al., 2020, Clemente et al., 2021, Park et al., 2022). Meanwhile, for medicine, some applications and software that are focused on complex, clinically based scenarios are available for use in virtual group discussions to improve students' decisionmaking and diagnostic skills. However, for dentistry in general, and prosthodontics, in particular, there are few options available for students.

Artificial intelligence (AI) is being increasingly adopted in the field of dentistry, including dental education. While other technologies, such as robotics, are expensive and require a certain environment in which to operate, AI can be delivered at much lower costs and to a wider range of students.

Regarding the sequence of the learning activities, most of the respondents opted for teaching, individual study and discussions. The students considered it more opportune for the student–instructor and student–student interactions/discussions to be taken after the lecture series and individual study. This sets a high priority on individual study with the possibility to clear up some difficult subjects during discussions with members of the teaching staff (Kunin et al., 2014).

Clinical training should be performed using clear and understandable content and focusing on the practical usage of the presented information, engagement of the students in different and attractive tasks, high interactivity between the participants to the study group, and, not the least, by an enthusiastic and dynamic approach on the part of the professor. At the same time, the optimal assimilation of information should be supported through discussions/debates on relevant clinical situations, as pointed out by the students' answers.

According to the results of this study, clinical training was the major challenge during pandemic crises. Despite the high acceptance of new digital tools, not all students embraced online learning, since there is a need for consistent enhancement of these tools to support clinical training. In the context of the limited availability of virtual or enhanced reality, proper digital tools (virtual reality-based technology, virtual patients, PBL, CBL etc.) can improve clinical reasoning and decision making. Still, for practical skills training, direct contact with the patient is mandatory. None of the other available methods were able to compensate for the lack of practical skills training.

Conclusions

Within the limits of this study and referring only to our study group, the second and third year, dental technique specialization, we can conclude that students are familiar with the modern methods and materials used in CAD-CAM and 3D Printing technologies and consider them useful for their future activity in dental technique laboratories.

At the same time, most of them express concern that with the introduction of digital technologies, the role of dental technicians may be diminished. This research suggests that efforts should be made to improve students' knowledge base on these future methods in dental prosthetics.

All these modern technologies allow the elimination of many laboratory steps, which greatly reduces the risk of errors. In addition, these methods are using industrially manufactured materials, with a more homogeneous internal structure and a mechanical resistance that is significantly higher than the usual materials used in the laboratory.

These technologies are currently all available, but not fully integrated. Education influences dental practice and dental schools should be more concerned about training students on the use of digital technology in dentistry.

The familiarity of students with digital technology is a key feature that may positively influence the adoption of digital technology in the broader community of interest.

Technology affords to improve self-assessment and can even provide for a virtual learning environment. Consequently, dental students gain objective and visual feedback that permits enhanced self-assessment.

In what concerns the remote learning, for dental education in particular, the disruption imposed by this pandemic revealed once more the importance of direct contact of students with teaching staff and with patients. Regardless of the progress in computer technology used for online teaching, there is a unanimous opinion that dentistry is not a domain that can be predominantly taught online. However, online teaching can be a substantial addition to the traditional on-site method. These technologies should be integrated into the educational process as an instrument to boost the trainer's ability to engage students and improve their practical skills

CHAPTER 3

THE IMPORTANCE OF CLINICAL EVALUATION AND MATERIALS USED IN PROSTHETIC TREATMENT

1. State of art

Oral health is an essential part of general health but is underappreciated in approaches for the promotion of individual and public health. Several studies have investigated the relationships between edentulism and a series of general disease- cardio-vascular, blood, neural, gastro-intestinal, urogenital, metabolic diseases, allergies, non-specific or specific infections (Hepatitis, HIV), head and neck conditions including, nasal or sinus surgery and laryngeal or oro-pharyngeal complaints.

The links between poor health conditions and edentulism are obvious, and it was concluded that general diseases condition the choice of therapeutic solution and vice versa, dental treatment can influence, for better or worse, the general condition of the patient (Nitschke et al., 2021).

The number of general diseases increases with age as does the number of drugs regularly consumed, which coincides with the onset of oral diseases and tooth loss was even suggested as a marker of general health and socio-economic condition.

One of the frequent causes of edentation is periodontal damage and it has been demonstrated that the role of local and systemic risk factors for periodontal disease is determinant. A number of systemic diseases and conditions are thought to influence the ability of the human body to respond with good efficiency to the aggression of pathogenic bacteria. These include diabetes, rheumatoid arthritis, atherosclerosis, obesity, or even physiological hormonal changes which normally occur throughout life (Das et al., 2019, Xu et al 2020, Mazur et al., 2020).

Postmenopause is a term to describe the post-menopausal stage. In the postmenopausal period, menstruation has disappeared for more than 12 consecutive months. Menopausal symptoms, which may include hot flashes and night sweats, vaginal dryness and sexual discomfort, depression, insomnia, changes in sexual appetite, dry skin, weight changes, hair loss, or urinary incontinence, may become milder or may disappear completely.

However, some people continue to experience menopausal symptoms for a decade or more after menopause (Twardowski et al., 2021).

Importantly, the menopausal and postmenopausal periods are characterized by a deficiency of sex hormones, estrogen and progesterone, hormones that, in normal concentrations, have an osteo-protective role. Bone metabolism is influenced by the menopause onset, with subsequent estrogen deficiency altering the rate of bone loss (Levin et al., 2018).

Hormone deficiency can lead to osteopenia and later, osteoporosis. Of course, a number of other factors have been associated with the risk of developing osteoporosis, such as: age, the phase of involution of bone mass that occurs after adulthood between 35 and 40 years, accelerated bone loss in both sexes; genetics, with a decisive role in regulating bone density, along with skeletal geometry and bone turnover; nutrition, with a deficit in vitamins and minerals; behavioral issues, including sedentary lifestyle, smoking, or use of other harmful substances (Rachner et al., 2011).

The treatment of the patient with periodontal impairment includes, first of all, the removal of the risk factors, which, in the first stage, involves, in addition to the patient's motivation and awareness, professional hygiene techniques (Elkerbout et al., 2022)

Also, loco-regional diseases at the level of the temporo-mandibular joint, sinuses, salivary glands, influence the choice and prognosis of prosthetic treatment.

The presence of odontogenic cysts, changes in the articular elements or sialolithiasis often require surgical interventions before dental treatment, which underlines the value of multidisciplinary patient management, including dermatology, endodontics, radiology, maxillofacial surgery, and pathology (Díaz-Belenguer et al., 2016, Raut et al., 2021).

Odontogenic sinusitis is a relatively frequent pathology, especially in certain age groups and it is still underdiagnosed due to its non-specific symptomatology; so it is imperative that the dental pathological process is resolved, otherwise an efficient, complete treatment is not possible.

In the majority of cases, maxillary sinusitis has a rhinogenic cause, but due to the relation of the maxillary sinus with the alveolar bone and projection of the roots of the canines, premolars, and (mainly) molars, it can also have a dental cause (Psillas et al., 2021, Taschieri et al., 2017, Peñarrocha-Oltra et al., 2020).

The type of prosthetic construction and the material from which it will be made are of particular importance in restoring this homeostasis.

A well-planned therapeutic strategy which could be adapted to the clinical situation is essential for the long-term outcome of prosthetic rehabilitation. Incorrect prostheses may contribute to the progression of periodontal disease because there is a strong association between prosthetics and periodontics, as periodontal health has an important role in the longevity of fixed dental restorations (Hsu et al., 2015, Mizrah et al., 2019, Tatarciuc et al., 2021).

Major concern in edentulous therapy is the restoration of function of dento-maxillary system, accordin to biological and biomechanical behavior of the individual and to the patient's needs and desires. Therefore, it requires the development of an artificial substitutes which gives the wearer the feeling of existence of his natural teeth, in the context of psycho-affective personality, preserving the patient's aesthetic characteristics (Vitalariu et al., 2015, Poddar et al., 2017). The insertion into the oral cavity of a prosthetic construction of such amplitude it doesn't just mean the restoration of altered or lost functions, but it also means the creation of a new balance between all the elements of the stomatognathic system. The planning of the therapeutic steps, having previously informed patient consent, is a fundamental point for the success of a dental treatment (Antohe et al., 2018). The choice of the optimal solution must be based on a correct and complete clinical examination, on the results of the general, loco-regional local and complementary examinations, on an objective evaluation of the patient's wishes and expectations. The difficulties of choosing a therapeutic treatment consist in finding a balance between satisfying the patient's requirements and the objective possibilities in the oral cavity (Patel et al., 2018, Tatarciuc et al., 2019). It is recommended to design prosthetic constructions in a manner that they can be easily modified in case of tooth loss or other biological complications and also to offer the opportunity to integrate perfectly with the elements of the stomatognathic system, optimally restoring its functions.

My contributions to this research direction can be found in the following articles:

1. Laza G-M, Sufaru I- , Martu M-A, Martu C, **Diaconu-Popa DA**, Jelihovschi I, Martu S. Effects of Locally Delivered Minocycline Microspheres in Postmenopausal Female Patients with Periodontitis: A Clinical and Microbiological Study., *Diagnostics* 2022; 12, 1310. **https://doi.org/10.3390/diagnostics12061310** IF 3,992

2. Martu C, Martu M-A, Maftei G-A, **Diaconu-Popa DA,** Radulescu L. Odontogenic Sinusitis: From Diagnosis to Treatment Possibilities—A Narrative Review of Recent Data. *Diagnostics* 202; 12, 1600. **https://doi.org/10.3390/diagnostics12071600**. IF 3,992

3. Murariu A, Baciu E-R, Bobu L, **Diaconu-Popa D,** Zetu I, Geletu G, Vasluianu R-I, Hurjui L. Knowledge, Practice, and Awareness of Oral Cancer and HPV Infection among Dental Students and Residents: A Cross-Sectional Study, *Medicina* 2022, 58, 806. **https://doi.org/10.3390/medicina58060806**. IF 2,948

4. Mârtu I, Murariu A, Baciu E-R, Savin CN, Foia I, Tatarciuc, M **Diaconu-Popa D.** An Interdisciplinary Study regarding the Characteristics of Dental Resins Used for Temporary Bridges, *Medicina* 2022, 58, 811. **https://doi.org/10.3390/medicina58060811**. IF 2,948

5. Jitareanu A, Agoroaei L, Aungurencei OD, Goriuc A, **Diaconu Popa D**, Savin C, Caba I-C, Tatarus S, Profire B, Mârtu I. Electronic Cigarettes' Toxicity: From Periodontal Disease to Oral Cancer. *Appl. Sci*. 2021, 11, 9742. **https://doi.org/10.3390/app11209742m**. IF= 2.838

1. POSSIBILITY OF EVALUATING AND BALANCING THE ORAL STATUS IN PROSTHETIC THERAPY

Introduction

Periodontitis is an inflammatory disease of the tissues that serve to maintain and sustain the functionality of the teeth on the dental arches. Its etiology is often multifactorial, the main cause being the onset of periodontal dysbiosis, in favor of anaerobic gram-negative bacteria (Van Dyke et al., 2020). Human body will react to this dysbiosis through innate and adaptive defense mechanisms, with the manifestation of an inflammatory response, detectable at molecular and clinical levels. If the causal factors are not removed, the inflammation may evolve, turning initially reversible lesions into attachment losses, with the onset of periodontitis (Gibertoni et al., 2017).

First direction of this study focuses on Type II Diabetes Mellitus (DM) patients with periodontitis; type II DM is a metabolic disease, often the consequence of an inadequate diet, which may be associated with other predisposing factors (tobacco use, alcohol, genetic factors, etc.) (Namayandeh S.M et al., 2019). These include changes of a micro- and macro-vascular nature, which make DM the leading cause of blindness (diabetic retinopathy), amputation of the lower limbs, kidney failure, hypertension or even death from cardiovascular causes (Eschwège et al., 2000). Periodontal disease has been identified as the sixth complication of DM, as a result of a combination of mechanisms that include reduced immune response capacity in the patient with diabetes, increased markers of inflammatory and oxidative stress through the production of advanced glycation end-products (AGEs) and tissue healing deficits. Of course, the manifestations of these complications are all the more important as the metabolic control is more deficient (Elkerbou et al., 2022).The treatment of the patient with periodontal impairment includes, first of all, the removal of the risk factors, which, in the first stage, involves, in addition to the patient's motivation and awareness, professional hygiene techniques.The majority of clinical trials have suggested that non-surgical periodontal debridement improves glycemic control among individuals with type 2 diabetes mellitus (Jain et al .2019, Madianos et al., 2018). So, first it was investigated the local, periodontal response to treatment of a particular group of subjects, prone to severe periodontal destructions and impaired healing and second, it was analyzed any potential supplementary benefits other than those already demonstrated by scaling and root planning. .

Electronic cigarettes, very popular in the last decade, can influence the state of the oral mucosa and periodontal tissues. The evaluation of the toxicological profile of e-liquids and e-vapors is quite difficult because of the lack of knowledge about their chemical composition, and exposure also depends on the device's characteristics, such as voltage and temperature. In the studies we carried out, we set out to highlight the impact of electronic cigarettes on periodontal tissues and oral cancer initiation.

The changes at the oral level are also determined by the alteration of the hormonal balance and it is obvious that women are more affected by these variations. In the postmenopausal stage, due to the decrease in estrogen, there is a noticeable change in the production of various growth factors and reduced osteoblastic activity, leading to an acceleration of destruction and a decrease in bone formation, with harmful effects because the loss of attachment periodontal disease is increased (George et al., 2020). The main aim of our study was to investigate the effects of local therapy with minocycline microspheres on species of the Socransky red complex (P. gingivalis, T. forsythia, and T. denticola) in postmenopausal female patients with moderate and severe periodontitis, starting from the hypothesis that this combined therapy will decrease the bacterial species prevalence in deep periodontal pockets.

Practicing dentists can treat periodontal diseases with conventional therapies; however, restoration of the damaged periodontium is not yet feasible. Regenerative periodontal therapy has attempted to rebuild periodontal supporting tissues, including alveolar bone, gingiva, periodontal ligaments (PDLs), and cementum. In addition to tissue regeneration, damaged periodontal tissues can be repaired by applying stem cells, growth factors, or an extracellular matrix scaffold (Mira et al., 2017). Among the stem cells studied thus far, those that have proven to have an important role in the regeneration of periodontal tissues are mesenchymal stem cells (MSCs), embryonic stem cells (ESCs), and induced pluripotent stem cells (iPSCs). MSCs are preferred for use in regeneration because they do not present ethical problems in the manner of ESCs (Roberts et al., 2015). In addition, they have been shown to contribute to periodontal regeneration when transplanted into periodontal bone defects, being isolated from bone marrow mesenchymal stem cells (BMSC). However, this technique has not proven to be advantageous because of the associated pain during harvesting and the low number of harvested cells; therefore, researchers have tried to collect stem cells from dental tissues, such as the ligament, the gum, dental follicles, dental pulp, apical papilla, and exfoliated human deciduous teeth (Baraniya et al., 2020, Gaudilliere et al., 2019). Contemporary investigations based on stem cells refer to tissue engineering methods aiming to regenerate periodontal tissues, which include the regenerative processes that can occur at the level of the periodontium and the entire tooth (dental pulp, root, dentine, and alveolar bone) In the analysis that was carried out regarding this treatment method, we analyzed the current state of research in the field.

The results of the possibilities of evaluation and treatment regarding prosthetic therapy are illustrated by the following publications:

1 Sufaru.I-G , Martu M-A , Luchian I, Stoleriu S, **Diaconu-Popa D**, Martu C, Teslaru S, Liliana Pasarin L, Solomon SM. The Effects of 810 nm Diode Laser and Indocyanine Green on Periodontal Parameters and HbA1c in Patients with Periodontitis and Type II Diabetes Mellitus: A Randomized Controlled Study, *Diagnostics* 2022, 12, 1614. https://doi.org/10.3390/diagnostics12071614. IF 3.992
2.Laza G-M, Sufaru I-G , Martu M-A, Martu C, **Diaconu-Popa DA**, Jelihovschi I, Martu S. Effects of Locally Delivered Minocycline Microspheres in Postmenopausal Female Patients with Periodontitis: A Clinical and Microbiological Study., *Diagnostics* 2022; 12, 1310. https://doi.org/10.3390/diagnostics12061310 IF 3,992
3. Jitareanu A, Agoroaei L, Aungurencei OD, Goriuc A, **Diaconu Popa D**, Savin C, Caba I-C, Tatarus S, Profire B, Mârtu I. Electronic Cigarettes' Toxicity: From Periodontal Disease to Oral Cancer. *Appl. Sci*. 2021, 11, 9742. https://doi.org/10.3390/app11209742m. IF= 2.838
4.Goriuc A, Foia L, Cojocaru K, Diaconu-Popa D, Sandu D, Luchian I. The Role and Involvement of Stem Cells in Periodontology. *Biomedicines* 2023, 11, 387. https://doi.org/10.3390/biomedicines11020387. IF 4.757

Materials and method

In order to analyze the effect of conservative treatment to the patients with periodontitis and Type II Diabetes Mellitus a prospective, randomized controlled, single-blind interventional study was performed on 49 patients diagnosed with periodontitis and type II diabetes. The methodology of the study was in accordance with the rules set out in the Declaration of Helsinki and was approved by the Bioethics Commission of the institution. All study participants signed the informed consent form and were aware of their right to withdraw from the study at any stage of the study without being subject to any sanctions.

The study included male and female subjects, diagnosed with type II diabetes mellitus t (DM), and who presented periodontal probing depths higher than 5 mm upon periodontal examination. Exclusion criteria were represented by: systemic diseases other than diabetes, smoking, history of antibiotic therapy, anti-inflammatory therapy or periodontal treatment in the last 3 months; significant changes in DM treatment during the study period.

Based on previous findings (Zhang H.et al 2013) a probing depth (PD) reduction of 1 mm was used to determine the size of the groups, with a power of 90%, and alpha set to 0.05, resulting in an optimal size of 22 subjects per group. However, in order to counteract potential withdrawals from the study, we set a size of 25 patients per group, estimating an abandonment rate of 10%. The 50 resulting subjects were, thus, divided into two groups: patients who followed scaling and root planing therapy (n = 25) (SRP group) and patients who followed SRP and aPDT therapy with diode laser and indocyanine green (n = 25) (SRP + aPDT group); one patient who did not attend all aPDT sessions was finally excluded from the study group.

There were no significant differences in age between the two groups (p = 0.734) (Table XIII). The distribution of patients to one of the two groups was randomized, through a system of sealed envelopes. Participants were offered randomly generated treatment assignments in sealed opaque envelopes, doubled with carbon paper, the therapeutic operator not being involved in making the envelopes.

Table XIII. Demographic parameters for study groups at baseline and after 6 months.

Parameter	**SRP Group SRP**	**SRP +aPDT Group**
Subjects number (n)	**25**	**24**
Number of sites	**474**	**445**
Age (years) (mean standard deviation)	**55.24±3.41**	**55.58±3.62**
Male n (%)	**14 (56%)**	**13 (56.16%)**
Female (%)	**11 (44%)**	**11(45.84%)**

For each patient included in the study, the following periodontal parameters were determined the simplified plaque index (PI), bleeding on probing index (BOP), probing depth (PD), established by inserting the periodontal probe into the periodontal pocket, evaluated at six points per tooth (mesial–buccal, buccal, distal–buccal, mesial–lingual, lingual, distal–lingual), periodontal clinical attachment loss (CAL). A North Carolina No.15 Periodontal Probe (Hu-Friedy, Chicago, IL, USA) was used for clinical measurements. All periodontal assessments were performed by an experienced qualified examiner. Clinical examinations were performed blind to the type of treatment followed by the subjects at baseline (T0) and 6 months apart (T1).

For the analysis of glycated hemoglobin, venous blood was collected in 3 mL vacutainer with EDTA K3 (FL Medical, Torreglia PD, Italy). The quantification of glycated hemoglobin in total hemolyzed blood was based on a turbidimetric inhibition reaction, as previously described (Anton D et al 2021; Zaharescu A.et al 2021). Glycated hemoglobin A1c (HbA1c) was determined for each patient at baseline and after 6 months. The method of determining HbA1c was immunoturbidimetric (Boehringer Mannheim, Baden-Wurttemberg, Germany), a test characterized by high specificity for anti-HbA1c antibodies.

All patients in the SRP and SRP + aPDT groups underwent non-surgical periodontal treatment, which involved ultrasound scaling (Woodpecker UDS-A-LED, Guilin Woodpecker Medical Instrument Co., Ltd., Guangxi, China) and root planing (Gracey Standard and Mini—Hu-Friedy, Chicago, IL, USA) (SRP), in one session. All patients were instructed in the technique of brushing their teeth and to avoid rinsing with antiseptics during the study. Patients in the study group also received aPDT therapy with diode laser and indocyanine green. For the preparation of the photosensitizer, the indocyanine green powder (ICG Pulsion, PULSION Medical Systems SE, Feldkirchen, Germany) was mixed with pure water, with a ratio of 5 mL water to 25 g bottle of powder, to obtain a concentration of 5 mg/mL according to the manufacturer's instructions. Since the aqueous solution of indocyanine green is unstable and must be used within 24 h, the fresh solution was prepared whenever necessary and the excess was discarded. The laser system used in the present study was a diode laser (A.R.C. Laser GmbH, Nuremberg, Germany) with a wavelength of 810 nm. Based on previous findings (Raut C.P et al 2018; Sethi K.S.et al 2019), the laser was applied continuously with a power of 0.2 W and a total energy of 12 J. In the periodontal pocket 1 mL of indocyanine green solution was inserted with a blunt needle and left in place for 60 s. The pocket was immediately irradiated with a diode laser by placing the tip in the pocket and moving it circumferentially around the tooth for 60 s. The procedure was repeated at 7, 14 and 21 days.

All the patients were instructed to follow the nutritional recommendations and to continue their normal physical activity throughout the study.

All data were recorded in individual patient records, stored and statistically analyzed.

For statistical analysis we used Microsoft Excel 2021 software (Microsoft, Washington, DC, USA) and Wizard 2 for Mac (Evan Miller®). The Shapiro–Wilk test was performed to determine the normality of the data distribution. The normally distributed values were compared with the t-Test and for the abnormally distributed values we used the Mann– Whitney test. The significance level was set at $p < 0.05$. The Pearson correlation test was used to determine the relationship between clinical parameters and HbA1c.

To follow the possibilities of oral treatment of post-menopausal female subjects (no menstrual bleeding for at least 12 months), diagnosed with periodontitis a study was conducted on 62 subjects, in the Periodontal Clinic of the Faculty of Dental Medicine, "Grigore T. Popa" University of Medicine and Pharmacy. The exclusion criteria were represented by: smoking, systemic diseases other than osteoporosis, history of periodontal treatment or antiseptic/antibiotic/anti-inflammatory drugs in the last 3 months, hormone replacement therapy, or use of bisphosphonates.

The patients were informed regarding the study protocol and the signed informed consent was obtained from each subject. The study was conducted according to the Helsinki Declaration norms and was approved by the Ethics Committee, Approval Form/25May 2020.

Each subject followed a dual energy X-ray absorptiometry test (DEXA) hip examination at baseline, in order to evaluate bone density, with the T-score interpretation as follows: normal (between 1 and -1), osteopenia (between -1 and -2.5), and osteoporosis (-2.5 or lower). All the subjects followed a comprehensive clinical dental examination which included the measurements of the following periodontal parameters: probing depth (PD), clinical periodontal attachment loss (CAL), and bleeding on probing index (BOP). The measurements were performed by two experienced and calibrated examiners, with an agreement of 99.20%, using the periodontal probe (Williams Probe PQW, Hu Friedy Mfg. Co., LLC, Des Plaines, IL, USA). The diagnosis of periodontitis stages 2–3 was based on the current periodontitis classification: CAL higher than 3 mm, PD higher than 5 mm.

Full-mouth ultrasonic scaling (Woodpecker UDS-A-LED, Guilin Woodpecker Medical Instruments Co. LTD, Guangxi, China) and root planing (Gracey curettes, Hu Friedy Mfg. Co., LLC, Des Plaines, IL, USA) were performed in one session for each subject. In addition, minocycline HCl microspheres 1 mg, incorporated into a bioresorbable polymer, polyglycolide-co-dl-lactide (PGLA) (Arestin®, OraPharma, Bausch Health US, LLC, Bridgewater, NJ, USA), were placed in periodontal pockets. The antibiotic comes as a dry powder, packaged in a unit-dose cartridge, which is inserted into a spring-loaded mechanism. After isolating and gently drying the recipient site, the product was slowly injected into the periodontal pocket. Oral hygiene instructions were given in terms of tooth brushing and dental flossing, and the patients were required to avoid the use of antiseptics, antibiotics, or anti-inflammatory drugs throughout the study period. The BANA test (N-benzoyl-dl-arginine-beta-naphtylamide) (PerioScan, Oral B, Belmont, CA, USA) was performed in order to detect the presence of Porphyromonas gingivalis, Tannerella forsythia and Treponema denticola. This qualitative colorimetric test was performed chair-side, according to the manufacturer's indications. The sites were isolated and gently dried; supragingival plaque was removed, and subgingival plaque samples were collected with a sterile curette and placed on the test paper. The results were analyzed according to the following scores: 0 (absence, no staining), 1 (weak presence, small traces of color), and 2 (presence, dark color). The totalnumber of tested sites was 2184 and the clinical measurements and BANA tests were performed at baseline and repeated after 3 months. All the data were registered for each subject and statistically analyzed (Microsoft Excel 2021 andWizard 2 for Mac, ®Evan Miller). A Shapiro–Wilk test was conducted as a normality test; and normally distributed values were compared with a paired t-Test, while for non-normally distributed values we used a Mann–Whitney U test. Pearson's correlation test was used to measure the linear correlations.

Another factor that could influence the oral environment is represented by the toxicity of traditional cigarettes or electronic cigarettes. In order to follow their effects on the oral tissues, we conducted a review type study that makes an up-to-date extensive presentation of the possible mechanisms that associate electronic cigarette smoking with increased prevalence and progression of oral cancer.

In order to have an overall picture, in our study we followed several aspects the effects of electronic cigarettes on the oral cavity, the potential mechanisms involved in oral cancer development associated with electronic cigarette smoking, the chemical composition of e-liquids and vapors and the implications in oral carcinogenesis an the nicotine's influence on chemotherapy drug resistanc

Results

The study of the effects of 810 nm diode laser and Indocyanine Green on periodontal parameters and HbA1c in patients with periodontitis and type II Diabetes Mellitus was completed in a SRP group of 25 subjects (474 sites, with a mean of 18.96 ± 4.48) who followed only SRP and a SRP + aPDT group of 24 subjects (445 sites,with a mean of 18.54 ± 4.07) that followed SRP + aPDT. The PI values in the SRP group were 79.44 ± 6.31 and 80.04 ± 5.90 for the SRP + aPDT group, with no statistically significant difference (p = 0.732). After 6 months, PI showed significant decreases for both the SRP and the SRP + aPDT groups (17.72 ±6.38, p < 0.001 and 17.08 ± 5.14, p < 0.001, respectively), with no statistically significant difference between groups at +6 months either (Table XXI). For BOP, the values at baseline were of 67.76 ± 6.57 in the SRP alone subjects and 68.67 ± 6.10 in the SRP + aPDT subjects, with a p = 0.620. The assessments after 6 months showed significant decreases for both groups: 8.08 _±5.09 for the SRP group (p < 0.001) and 4.21 ±3.85 for the SRP + aPDT group (p < 0.001); moreover, the decrease was more significant for the SRP + aPDT subjects (p < 0.001).

PD and CAL followed the same trend as BOP. At baseline, the PD and CAL values for the SRP group were of 5.54 ± 0.24 mm and 4.51 ± 0.20 mm, respectively; the values in the SRP + aPDT group were of 5.53 ± 0.24 mm and 4.50 ± 0.22 mm, with no statistically significant differences between the groups (p = 0.878 and p = 0.951, respectively).
After 6 months, both parameters showed significant decreases; for the SRP group PD=4.10±0.22 mm, p<0.001 and CAL=3.154±0.17, p<0.0001; for the SRP+aPDT group, PD=3.56±0.19, p<0.0001 and CAL=2.58±0.19, p<0.0001. The decrease for PD and CAL were more significant in the subjects with SPR+aPDT (table no XIV).

Table XIV. Clinical parameters for study and after 6 months

Table 2. Clinical parameters for study groups at baseline and after 6 months.

Parameter	SRP Group (n = 25)			SRP + aPDT Group (n = 24)		
	Baselin *	+6 Month *	Δ #	Baselin *	+6 Months *	Δ #
PI	79.44 ± 6.31	17.72 ± 6.38 a	62 (60–66)	80.04 ± 5.90	17.08 ± 5.14 a	63 (60–67)
BOP	67.76 ± 6.57	8.08 ± 5.09 a	60 (55–66)	68.67 ± 6.10	4.21 ± 3.85 ab	65 c (55–69)
PD (mm)	5.54 ± 0.24	4.10 ± 0.22 a	1.4 (1.4–1.5)	5.53 ± 0.24	3.56 ± 0.19 ab	1.9 c (1.8–2.2)
CAL (mm)	4.51 ± 0.20	3.15 ± 0.17 a	1.40 (1.20–1.50)	4.50 ± 0.22	2.58 ± 0.19 ab	1.95 c (1.70–2.10)

Δ: level of decrease between evaluations; PI: Plaque Index; BOP: Bleeding on Probing Index; PD: probing depth; CAL: clinical attachment loss; * Values are expressed as Mean ± Standard Deviation; # Values are expressed as Median (Min–Max); a Intra-group $p < 0.05$ after 6 months (*t*-Test); b Inter-group $p < 0.05$ at the same time of evaluation (*t*-Test); c $p < 0.001$ (Man-Whitney test).

The values of HbA1c were 3 6.52±0.25 for the SRP group and 6.53±0.24 for the SRP+aPDT group (p<0.900). Both treatment options generated significant and similar reactions for HbA1c for both groups. The HbA1c value for SRP group after six months was 6.28±0.24, p=0.0001, the value for the SRP+aPDT group was 6.262±0.040, p<0.0001 and Δ values of 0.244for the SRP alone and of 0.26±0.19 for the SRP+aPDT (fig.61, fig.62).

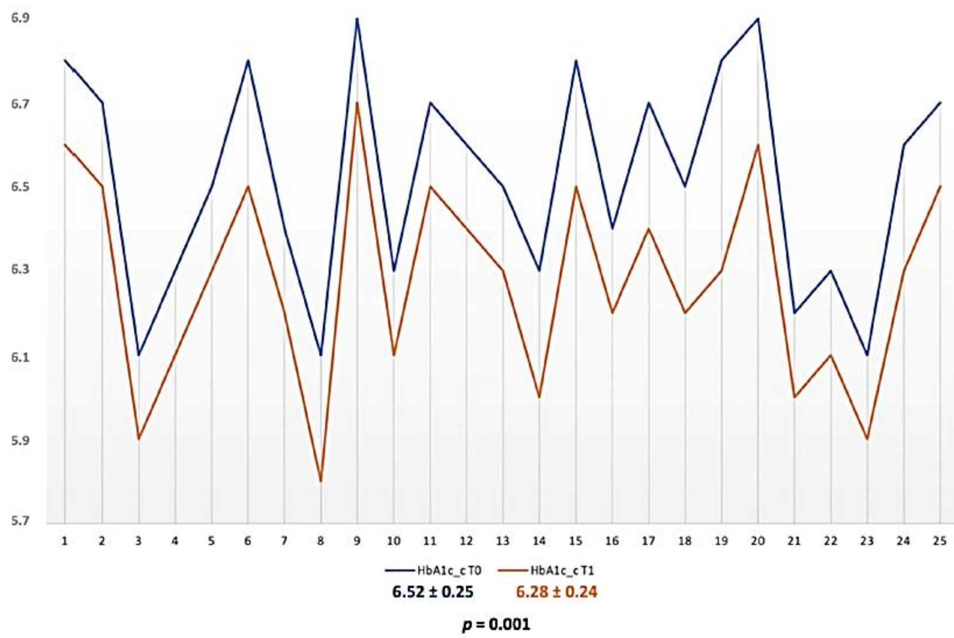


Fig.61 HbbA1c variations in the SRP group

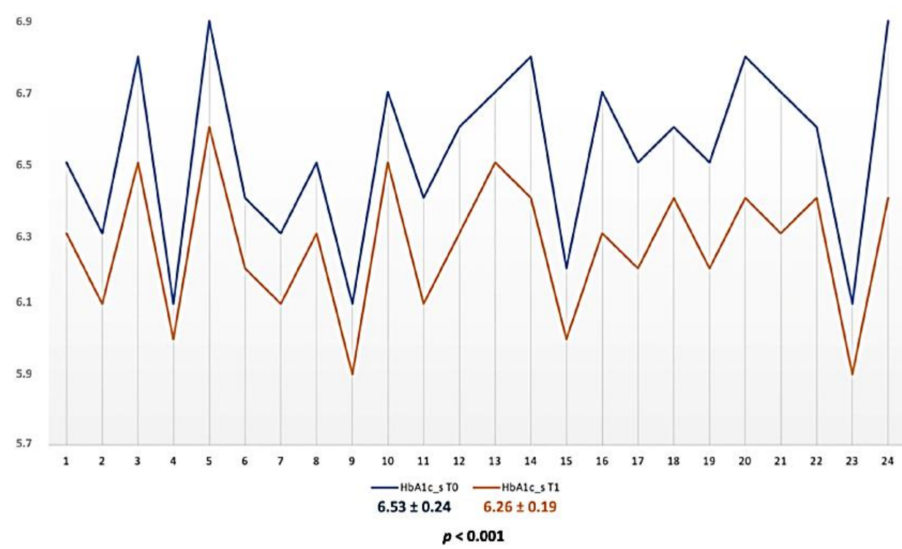


Fig.62 HbA1c variations in the SRP + aPDT group

It was found a strong positive correlation between HbA1c and tissue loss parameters (PD and CAL) in both groups. In the SRP group, we observed a $\rho = 0.922$ and $\rho = 0.896$ for PD at baseline and +6 months, respectively; for CAL the values were $\rho = 0.796$ and $\rho = 0.809$; also, the decrease in HbA1c (ΔHbA1c) correlated with ΔPD and ΔCAL ($\rho = 0.773$ and $\rho = 0.491$, respectively). In the SRP + aPDT group, the coefficients were $\rho = 0.989$ and $\rho = 0.995$ for PD at baseline and +6 months, respectively; for CAL the values were $\rho = 0.918$ and $\rho = 0.794$; also, the decrease in HbA1c (ΔHbA1c) correlated with ΔPD and ΔCAL ($\rho = 0.963$ and $\rho = 0.697$, respectively). The treatment regime was well tolerated, without any significant side effects. Two patients in the SRP +aDT group reported slight discomfort due the local heating during aPDT.

The study on the Minocycline microspheres locally delivered to postmenopausal female patients with periodontitis was conducted on 62 post-menopausal female subjects with a mean age of 59.98 ± 4.02 years old. At the 3-month evaluation, we observed significant reductions of probing depth (from 6.05 ± 0.36 mm to 5.12 ± 0.33 mm, $p < 0.001$), clinical attachment loss (from 5.11 ± 0.59 mm to 4.45 ± 0.57 mm, $p < 0.001$) and bleeding on probing (from 78.19 ± 5.00 to 11.54 ±6.05 2.78, $p < 0.001$) (Table XV).

Table XV Changes in periodontal clinical parameters

	Baseline (T0)	**After 3 month (T1)**
PD (mm)	6.05 ± 0.36	5.12 ± 0.33*
CAL (mm)	65.55 ± 0.59	4.45 ± 0.57*
BOP	78.10 ± 5.99	511.54 ± 2.78*

PD-probing depth, CAL-clinical attachment loss, BOP-bleeding on probing, values expressed as mean ± standard deviation,* $p<0.0001$

At three months, all three pathogens showed significant reductions (table XVI)

	Baseline (T0)	**After 3 month (T1)**
Porphyromonas gingivalis	84.78 ± 06.74	10.75 ± 3.55*
Tannerella forsythia	61.91 ± 13.40	8.44 ± 2.01*
Treponema denticola	39.72 ± 6.50	7.53 ± 1.20*

After DEXA T-score-analysis, it was noticed that none of the patients presented normal density values (Between 1 and-1), 87.09% of the subjects had values between -1 and -2.5 and 12.91% presented values lower than -2.5. mT-score negatively correlated to the probing depth and to clinical attachment loss at baseline are illustrated in figure no 63.

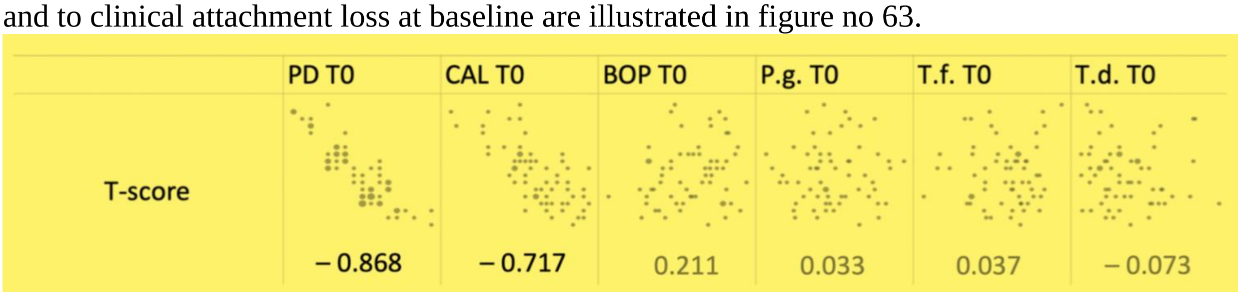


Fig.63 Correlation between T-score and clinical and microbiological data at T0. PD-probing depth, CAL-clinical attachment loss, BOP-bleeding on probing, P.g.-Porphyromonas gingivalis T.f. Tannerella forsythia, T.d.-Treponema denticola

Regarding the correlations between clinical and microbiological findings, the only correlation we could observe at baseline was a positive one between PD and CAL ($r = 0.726$, $p = 0.039$) and a negative correlation between T. forsythia and T. denticola ($r =$ □0.263, $p < 0.001$) (table XVII). At 3 months, the only correlation that was observed was between PD and CAL ($r = 0.686$, $p < 0.001$) (table XVIII)

Table XVII. Correlation coefficients (r) at T0

	PD T0	CAL T0	BOP T0	P.g. T0	T.f.T0	T.d.T0
PD	0	000000*	0.152733	0.280677	0.376881	0.792804
CAL T0		0	0.165768	0.487371	0.972045	0.399207
BOP T0			0	0.394453	0.433201	0.300487
P.g. T0				0	0.842481	0.113247
T.f.T0					0	0.039031*
T.d.T0						0

Table XVIII Correlation coefficients (r) at 3 months (T1).

	PD T1	CAL T1	BOP T1	P.g. T1	T.f.T1	T.d.T1
PD	0	0.00000-0*	0.971876T0	0.183483	0. 217513	0.166559
CAL T0		0	0.477021	0.623212	0.886567	0.477021
BOP T0			0	0.748079	0.253379	0.308013
P.g. T0				0	0.307023	0.286488
T.f.T0					0	0.828705
T.d.T0						0

PD: probing depth; CAL: clinical attachment loss; BOP: bleeding on probing; P.g.: Porphyromonas gingivalis; T.f.: Tannerella forsythia; T.d.: Treponema denticola; * statistical significance.

When analyzing the correlations between T0–T1 (D values) differences, we observed positive correlations between the CAL decrease and PD decrease ($r = 0.347$, $p = 0.006$), as well as between the CAL decrease and BOP decrease ($r = 0.275$, $p = 0.030$). We also found anegative correlation between T. denticola and T. forsythia decreases ($r =$ □0.264, $p = 0.038$) (table XIX).

Table XIX Correlation coefficients (r) of differences in values (D) T0 vs. T1.

	ΔPD T	ΔCAL T	ΔBOP T	ΔP.g. T	ΔT.f.T	ΔT.d.T
ΔPD	**0**	**0.005746***	**0.426438**	**0.907375**	**0.763760**	**0.683836**
ΔCAL T		**0**	**0.030416***	**0.828127**	**0.612912**	**0.345614**
ΔBOP T			**0**	**0.259398**	**0.504814**	**0.188132**
ΔP.g. T				**0**	**0.320476**	**0.1297842**
ΔT.f.T					**0**	**0.038469***
ΔT.d.T						**0**

PD: probing depth; CAL: clinical attachment loss; BOP: bleeding on probing; P.g.: Porphyromonas gingivalis; T.f.: Tannerella forsythia; T.d.: Treponema denticola; * statistical significance.

The research on the oral status of smoking patients shows that the habitual usage of different types of tobacco products (including smokeless tobacco) is associated with a higher risk of oral potentially malignant disorders and is an important etiological factor for oral cancer (Katarkar et al., 2015). Periodontal disease affects the supporting tissues of the teeth and is characterized by chronic inflammation status. There is a potential link between periodontal disease and oral cancer, and one mechanism that can explain this connection is particularly the chronic inflammation status associated with periodontal disease, which can affect normal cellgrowth control and induce carcinogenesis. Some studies confirm a relationship between periodontal disease and oral cancer (Yao et al., 2013, Lu et al., 2019).

Numerous microbial species colonize the oral cavity and form the oral microbiome and it is a well-known fact that cigarette smoking is a major factor for the alteration of the eubiotic balance, and there is also evidence that vaping can affect the profile of the oral microbiome, although the studies on this issue are still scarce. Dysbiosis can be characterized by the alteration of microbial diversity, with the loss of beneficial microorganisms, and excessive proliferation of the pathogenic microbes. This unbalance can reduce the host's ability to fight pathogens and increase the susceptibility to infections, and to carcinogenic compounds (Holliday et al., 2021, Almeida-da-Silva et al., 2021). In consequence, dysbiosis is associated with the initiation and progression of various oral diseases (dental caries, halitosis, periodontitis, and oral cancer) (Radaic et al., 2021, Lu et al., 2019).

Tissue damage, as a result of vaping, cannot only affect the integrity of gingival tissue but can also potentiate inflammatory responses, as well as setting up an optimal environment for bacterial growth. Pushalkar et al. investigated the effects of electronic cigarette aerosols on the human salivary microbiome and found that e-vapors exposure was linked to a higher abundance of periodontal pathogens. The proliferation of Veillonella and Porphyromonas was significantly higher in e-cigarette users, in comparison with conventional smokers and nonsmokers, and it was accompanied by high levels of proinflammatory cytokines (Pushalkar et al., 2020).

Oral microbiome alterations can be linked to the appearance of periodontitis and even oral cancer. Periodontal pathogens (S. anginosus, C. gingivalis, P. melaninogenica, F. nucleatum) determine an increase in markers of systemic inflammation including C-reactive protein, interleukin (IL)-1, IL-6, TNF-alpha, and MMPs, which may lead to carcinogenesis

(Javed et al., 2015, Sahingur et al., 2015). P. gingivalis, T. denticola, and F. nucleatum promoted oral cancer migration and aggressivity.

Therefore, the concepts of periodontal pathogen-mediated carcinogenesis, as well as antimicrobial-based cancer therapy have emerged (Almeida-da-Silva et al., 2021, Radaic et al., 2021). Furthermore, due to the direct interaction with the carcinogens from cigarette smoke and e-vapors, and to the fact that oral epithelium possesses xenobiotic enzymes capable of converting proximate carcinogens to reactive metabolites, this tissue becomes a major target for smoking/vaping-associated cancer (Tommasi et al., 2019, Holliday et al., 2021)

Electronic cigarettes functioning involves heating a mixture of propylene glycol, glycerol, nicotine, and different flavoring agents to produce vapors that are inhaled. All these ingredients potentially contribute to adverse oral health outcomes.

Although the e-liquids used for electronic cigarettes have a simple composition in comparison with traditional tobacco products, e-cigarettes were found to be a source of toxic and potentially carcinogenic tobacco-specific nitrosamines, tobacco alkaloids, and nicotine decomposition products, aromatic amines, heavy metals, and carbonyl compounds (Sancilio et al., 2017).

The number of e-cigarette brands and flavored products is impressive (over 8000 different flavorings). Many flavoring ingredients are labeled as “generally recognized as safe” (by the Flavors Extracts Manufacturers Association), but their evaluation was performed on food products (at ingestion), and not for inhalation toxicity.

Despite the banning of certain flavors from conventional cigarettes, these flavors are still used in all the other products, including e-liquids (fig.64).

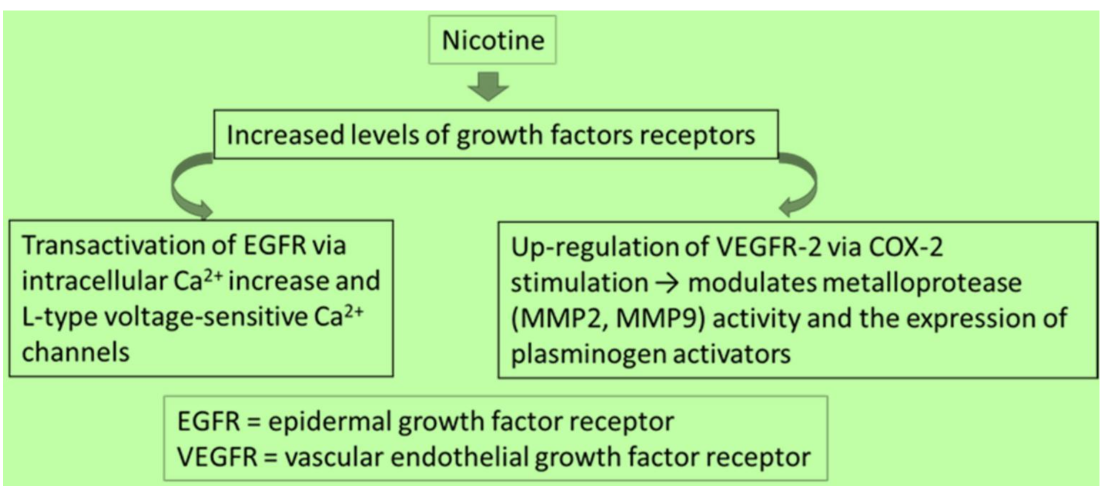


Fig.64 Effects of nicotine on growth factors receptor

In another studies it was identified a positive correlation between the cytotoxicity of different e-liquids and the total number and total concentration of flavor chemicals. The number of e-cigarette brands and flavored products is impressive (over 8000 different flavorings). Many flavoring ingredients are labeled as “generally recognized as safe” (by the Flavors Extracts Manufacturers Association), but their evaluation was performed on food products (at ingestion), and not for inhalation toxicity. Despite the banning of certain flavors from conventional cigarettes, these flavors are still used in all the other products, including e-liquids. Kaur et al.

make an extensive presentation of the main e-cigarette flavorings (table XX) and their toxic potential (Kaur et al 2018, Bitzer al 2018).

Table XX Toxic effects of flavoring ingredients in e-liquids

Flavors	Chemical Compounds Found in Flavoring Agents	Toxic Potential
Mint	**Menthol**	**Cytotoxic, oxidative, inflammatory, loss of epithelial barrier function**
Buttery	**Diacetyl**	**Oxidative, inflammatory, lung toxicity**
Chocolate	**Pyrazine derivatives**	**Cytotoxic**
Cherry	**Benzaldehyde derivatives**	**Oxidative, irritant, protein carbonylation of extracellular matrix, DNA damage**
Cinnamon	**Cinnamaldehyde**	**Cytotoxic, oxidative, loss of epithelial barrier function**
Vanilla	**Vanillin**	**Oxidative, cytotoxic, inflammatory, irritant**
Caramel	**Maltol**	**Oxidative, inflammatory, loss of epithelial barrier function**

To sum up, nicotine's anti-apoptotic potential can be explained through several mechanisms like the activation of the PI3K/Akt pathway, the overexpression of surviving, the induction of Bcl2 phosphorylation (as a consequence of PKC and ERK1/2 activation) (fig.65) . Bcl2 is an anti-apoptotic protein, and simultaneous treatment cisplatin and the activation of Bcl2 and induced resistance to cisplatin in cancer cells (Hsu et al 2020, Afrashteh Nour et al 2021).

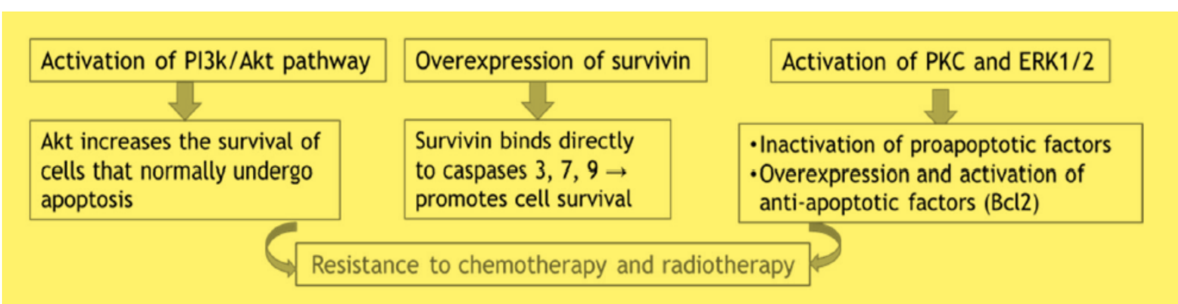


Fig.65 Nicotine apoptotic activity

Discussion

In the study investigated the effects of additional aPDT with indocyanine green to SRP versus SRP alone on periodontal clinical parameters in patients with type II diabetes and periodontitis: bacterial plaque index (PI), probing bleeding index (BOP), probing depth (PD) and loss of periodontal clinical attachment (CAL), along with HbA1c analysis, assessments performed at baseline and after six months. It is important to note that there were no statistically significant differences between the groups regarding all these parameters at baseline. At the six-month evaluations, we noticed statistically significant differences compared to baseline for all clinical parameters in both groups. Following comparisons between groups at six months, we noticed that there were no significant differences between PI values, unlike the studies conducted by Sethi and Raut (Sethi et al., 2019) or (Vangipuram et al., 2021) where PI was significantly lower in the SRP + aPDT group than in the SRP group. We specify that in the study there was a rigorous protocol of motivation and awareness of the patient, the brushing technique being clearly explained, with the reinstatement of the instruction whenever necessary. We also cannot ignore the fact that patients may have shown high compliance as a result of awareness of participation in a study (potential Hawthorne effect) (McCarney et al., 2007). We also recommended that patients avoid oral rinses with antiseptics during the study to avoid the risk of bias.

Moreover, in a systematic review and meta-analysis it was suggested that multiple applications of aPDT are more efficient in reducing periodontal pathogens compared to a single application (Jervøe-Storm et al., 2015). Based on these findings, our treatment protocol involved four sessions of aPDT. Statistically significant differences between groups appeared when comparing BOP, PD and CAL; subjects who followed SRP + aPDT showed more significant decreases than subjects who followed only scaling and root planing.

One study compared the antimicrobial efficacy of aPDT with indocyanine green, metronidazole gel, and chlorhexidine gel in vitro and reported that all of these modalities significantly reduced bacterial load (Fekraza et al., 2017). However, the major clinical disadvantages associated with chlorhexidine, including taste change and pigmentation of teeth and mucosa, were absent in the case of aPDT. In addition, Chiang (Chiang et al., 2020) demonstrated that cytotoxicity on oral cells by aPDT with indocyanine green was significantly less prominent compared to that of chlorhexidine.

The subgingival environment is characterized by lack of oxygen, which may not provide favorable conditions for better action of these traditional photosensitizers, while indocyanine green works even in the absence of oxygen (Bashir et al., 2021). Importantly, indocyanine green gets stimulated only in the presence of laser light, hence only the target (bacterial cells) gets affected in a dose-controlled fashion. Thus, there is a need to establish a standard protocol for the use of indocyanine green solution in periodontal therapy of aPDT, in terms of solution concentration, but also in the number of aPDT sessions. During the studies, including the present study, which used four sessions of aPDT, no adverse effects were reported to contraindicate the repetitive application of aPDT with indocyanine green. Two patients reported mild discomfort during aPDT application but did not require discontinuation of therapy.

HbA1c followed significant decreases in both subjects who had only scaling and root planing, and those with SRP + aPDT (0.244 0.014 for the SRP alone and 0.267 0.02 for the SRP + aPDT).

Nevertheless, even if minor, reductions of HbA1c can exert a considerable impact on the systemic status of the patient with type II diabetes, especially on its complications. Each 1% reduction in the mean HbA1c was associated with a 21% reduction in risk for diabetes related deaths, 14% for myocardial infarction and 37% for microvascular complications (Stratton et al., 2000).

What we noticed, however, in this study is that aPDT did not generate more significant effects on HbA1c than SRP alone; aPDT with indocyanine green had more statistically significant effects on BOP, PD and CAL, but not on PI and HbA1c. Therefore, this type of adjunctive therapy has the potential to generate supplementary clinical benefits to SRP on the periodontal destructive status of patients with type II diabetes, with no significant benefit to SRP in terms of glycemic control.

Of course, this study also has a number of limitations. Further investigations of our proposed therapeutic protocol on larger groups of DM and periodontitis subjects are required, with the inclusion of systemically healthy subjects as controls. We also did not assess the duration of diabetes illness, a factor which can negatively impact the evolution of periodontitis and the response to periodontal treatment (Kim et al., 2013). Even if the exact DM treatment variables were not investigated in detail, any changes in DM treatment or diet were considered as exclusion criteria.

Moreover, our study was predominantly clinical and we intend to continue and expand our investigations of the microbiological and molecular changes that could be generated by aPDT periodontal adjunctive treatment with indocyanine green in type II DM patients. Interesting observations might also emerge from comparative studies with other available photosensitizers, such as methylene blue, toluidine blue or curcumin. Moreover, further research could investigate the potential effects of this particular therapy in patients with other systemic conditions, such as osteo-articular, renal or cardiovascular diseases and periodontitis.

The study investigating the effects on clinical periodontal parameters and red complex perio-pathogens of locally delivered microspheres of minocycline HCl in post-menopausal female patients with moderate and severe periodontitis demonstrates the importance of knowing the general factors that influence the patients' oral status. In our study, we assessed the DEXA T-score at baseline, in order to provide data related to the bone density. Our T-score analysis generated a rather impressive image of low bone density values. None of the examined patients had normal bone density and a high percentage exhibited osteopenia (87.09%). There is plenty of literature data relating periodontitis to osteopenia/osteoporosis. A study conducted by Ayed MS (Ayed et al., 2019) on osteoporosis and healthy subjects observed that osteoporosis had a direct effect on the rate of progression of periodontitis that may be related to osteoporotic alveolar bone and/or changes in the subgingival environment. Alveolar bone density was significantly lower in osteoporosis patients than in healthy subjects.

In a cross-sectional study of 1329 postmenopausal women, systemic bone density was measured in the spine, hip, forearm, and whole body by DEXA (Brennan R.M et al., 2007).

The strongest associations were found between systemic bone density and CAL. Our findings are in accordance with these results, as T-score was negatively correlated to probing depth and clinical attachment loss at baseline. Contrary, in another study, T-score had a stronger correlation to the gingival bleeding index than to PD or CAL (Pereira et al., 2015).

Having in mind these particular conditions of high risk, different methods of periodontal treatment have been proposed. Besides SRP, which remains the gold standard therapy in every periodontitis case, adjunctive treatments using antibiotics, antiseptics, or photodynamic therapy have been used. In one of our previous research projects, which focused on the modulation of the hosts' inflammatory response, we found that sub-antimicrobial doses of doxycycline (Periostat®) exerted beneficial clinical effects in patients with osteoporosis, especially in deep periodontal pockets (Ursarescu et al., 2015).

The general disadvantage when using oral administration of antibiotics is generated by the potential side effects, while the concentrations in periodontal pockets might not reach the optimal value. In addition to kidney or liver toxicity, systemic antibiotics can lead to severe dysbiosis, with the development of resistant microorganisms. Therefore, locally delivered antiseptic or antibiotic substances seem to be preferred in certain cases (Greenstein et al., 2006). The most important issue related to local instillations or gel applications involves the high risk of being washed by the saliva flow. Over the years, new products have been developed in order to counteract this problem, including systems with a controlled time of drug release. Arestin® is a product with slow release minocycline included in PLGA-based microspheres. Minocycline is part of the tetracyclines group of antibiotics. It is a broad-spectrum antibiotic, with good anti-infectious effects on both Gram-positive and Gram-negative bacteria. Moreover, minocycline also proved anti-inflammatory, immune-modulatory, and antioxidant effects (Garrido-Mesa et al., 2011). Minocycline intake at doses of 100–200 mg/day for 7–14 days demonstrated its benefits in reducing periodontitis progression and promoting periodontal tissue healing (Basegmez C et al., 2011). On the other hand, PLGA microspheres are a suitable drug carrier, are biodegradable, and are already used in many medical devices (Bala I et al., 2004). The polymer microspheres will progressively resorb and minocycline is slowly released into the periodontal pocket for at least two weeks (Paquette et al., 2002).

There are various investigations on the positive effects of locally delivered minocycline but, to our knowledge, this is the first study that focused on post-menopausal patients.

Van Dyke et al. (Van Dyke T.E et al., 2002) observed more significant reductions in PD and CAL in patients who followed SRP + Arestin® than in patients with SRP alone. Our results support these findings, with reductions of PD and CAL of 0.93, 0.18 and 0.66 0.17 mm, respectively ($p < 0.001$ for both variables). In another study, Chackartchi et al.(Chackartchi et al., 2019) investigated the clinical benefits of using either a chlorhexidine chip or minocycline microspheres in patients with chronic periodontitis during supportive periodontal treatment; PD, CAL, and BOP were assessed at baseline, 3, 6, and 12 months. Both treatments induced significant periodontal improvements, also reducing the need-for-surgery index. We found this aspect particularly important, due to the high patient costs and discomfort associated to surgical procedures.

In our study, minocycline significantly reduced the prevalence of red complex bacteria at the 3 months evaluation, when compared to baseline ($p < 0.001$). Goodson et al. (Goodson et al., 2007) focused on the antimicrobial effect of minocycline microspheres associated to scaling and root planning. This particular combined treatment exerted significantly higher reductions of red complex bacteria counts, along with improvements in PD, CAL, and BOP. In another study, patients with periimplantitis who followed SRP + locally delivered minocycline microspheres had low bacterial levels of T. forsythia, P. gingivalis, and T. denticola over a 12-month period (Renvert et al., 2004). Teles et al. (Teles et al., 2021) investigated minocycline-resistant species percentage and taxonomy in saliva and subgingival plaque samples before and after minocycline microspheres application; the authors observed the similar clinical improvements but, more importantly, antibiotic resistance by Aggregatibacter actinomycetemcomitans, T. forsythia, and P. gingivalis was either absent or infrequent.

Contrary to these results, Killeen et al. (Killeen et al ., 2016) and Tabenski et al. (Tabenski et al., 2016) found no additional advantages of locally delivered minocycline versus SRP alone in deep periodontal pockets, in terms of clinical, immunological, and microbiological findings. In an observational cross-sectional study that analyzed the oral microbiota of postmenopausal women with and without osteoporosis, the authors found that 79% of patients with periodontitis had osteoporosis but no differences were found in the quality and quantity of the investigated bacteria (Hernández-Vigueras et al., 2016). An interesting aspect observed in our study is given by the negative correlation between T. forsythia and T. denticola in postmenopausal women. We consider that these aspects require further investigations, on levels beyond clinical research.

Further investigations are required in order to support the efficiency of locally delivered minocycline as adjunctive to the non-surgical periodontal therapy versus SRP alone in patients with low bone mineral density. In addition, supplementary research is necessary to compare the effects of this particular treatment with other local drug adjunctive therapies, such as photodynamic laser/LED assisted periodontal treatment. Also, the microbiological test we used is a qualitative one, conducted in the dental clinic. Quantitative analysis, such as polymerase chain reaction test, might offer a more accurate image for the benefit of locally delivered minocycline in terms of bacterial charge. Moreover, we consider that molecular investigations on pro-inflammatory cytokines and bone destruction markers are necessary in order to provide a more in-deep image of the underlying mechanisms and actions of minocycline in postmenopausal patients with periodontitis.

Regarding the local and loco-regional oral changes determined by smoking, there is scientific evidence that smoking minimizes the antioxidants activity. Several studies indicated that the reactivity of oxidants/reactive oxygen species found in e-cigarette aerosols is comparable to the one in conventional cigarette smoke (7 1011 free radicals/puff for e-cigarette vapors compared to 1014 in cigarette smoke), and that chronic exposure can cause systemic oxidant–antioxidant imbalance (Merecz-Sadowska et al., 2020, Dalle-Donne et al., 2020, Lerner et al., 2015, Lerner. et al, 2016).

The components from e-cigarette aerosols have the ability to disturb the function of the mitochondrial respiratory chain complexes, and mitochondrial malfunction is a key element in acute and chronic cellular stress (Isik Andrikopoulos et al., 2019).

Furthermore, the reorganization of the extracellular matrix and the disruption of collagen biosynthesis can be triggered by prolonged inflammation and oxidative stress (Lucas.et al., 2020). Oxidative stress also increased the expression of pro-apoptotic proteins, with a more pronounced effect seen for nicotine-containing e-liquids (Isik Andrikopoulos G et al., 2019) are over whelmed, structural alterations and DNA damage can appear.

The most abundant oxidative DNA lesions are considered to be 8-oxo-7,8-dihydro-2′-deoxyguanosine (8- oxo-dG), and exposure to e-vapors is linked to a higher frequency of 8-oxo-dG. Chronic oxidative stress can also cause impaired BER (base excision repair) activity, which reduces the efficiency of DNA repair (Merecz-Sadowska. et al., 2020, Lucas et al., 2020, Munther et al., 2019, Dalle-Donne et al., 2020).

The disruption of collagen biosynthesis can be triggered by prolonged inflammation and oxidative stress (Lucas et al., 2020). Oxidative stress also increased the expression of pro-apoptotic proteins, with a more pronounced effect seen for nicotine-containing e-liquids

Different studies demonstrated the genotoxic potential of nicotine. Nicotine-induced micronuclei formation in human gingival fibroblasts and in human primary parotid gland cells.

A higher frequency of micronuclei can be associated with a higher risk of cancer (Argentin et al., 2004, Ginzkey et al., 2014). However, in a cytological study that assessed the prevalence of micronuclei in oral cavity cells, there were no significant alterations in the micronuclei distribution in e-cigarette users in comparison to nonsmokers (Faridoun et al 2019).

Nicotine exposed cells presented increased comet tail length and -H2AX foci, signs of increased DNA strand breaks (Sundar et al., 2018). Nicotine can induce the over-expression of human telomerase reverse transcriptase mRNA in oral keratinocytes, which may play a role in the progression and malignancy of oral submucous fibrosis. This aspect is important because approximately 7–13% of patients with oral submucous fibrosis will eventually progress to oral squamous cell carcinoma (Sundar et al., 2016).

Our study emphasizes once again that local and general conditions influence the therapeutic strategy and have an impact on the oral integration and longevity of the prosthetic constructions.

Conclusions

A number of local and systemic factors can influence either the retention of periodonto-pathogenicbacterial plaque, with changes in its quantity and quality, or the ability of the immune system to effectively counteract bacterial aggression. Within the limitations of our study, the therapeutic protocol of four sessions with an 810 nm wavelength diode laser and 5 mg/mL indocyanine green as adjunctive to scaling and root planning resulted in statistically higher reductions in bleeding on probing, probing depth, and periodontal clinical attachment loss in patients with type II diabetes mellitus and periodontitis, when compared to SRP alone. Further investigations need to clarify the clinical and molecular advantages of using a photosensitizer that does not require the presence of oxygen in the microaerophilic deep periodontal pockets of DM patients.

Systemic diseases and local conditions are thought to influence the ability of the human body to respond with good efficiency to the aggression of perio-pathogenic bacteria. In the postmenopausal stage, due to the decrease in estrogen, there is a noticeable change in the production of various growth factors and reduced osteoblastic activity, leading to an acceleration of destruction and a decrease in bone formation, with harmful effects because the loss of attachment periodontal disease is increased. In our studies, the association of scaling and root planning with locally delivered microspheres of minocycline generated significant improvements in periodontal tissue loss, quantified by probing depth and clinical attachment loss, as well as in gingival inflammation, measured by bleeding on probing. This particular adjunctive therapy also exerted significant reductions in the prevalence of the red complex periodontal pathogens in postmenopausal female patients with moderate and severe periodontitis. Therefore, we observed that locally delivered microspheres of minocycline might represent an efficient adjunctive periodontal therapy in postmenopausal subjects with periodontitis and low bone mineral density.

The health impact of vaping is a subject of great interest, intensively debated by specialists in the field, due to the popularity of this habit. These products are called Modified Risk Tobacco Products and promise to offer a less harmful alternative for smokers. There is scientific evidence supporting the benefits of switching from conventional cigarettes to electronic nicotine delivery devices, including in the oral health area, but it is very dangerous to promote electronic cigarettes as low-risk products, especially among young people or pregnant women who are trying to quit smoking.

The oral tissues are extremely exposed to the potentially harmful effects of electronic cigarettes, and although many signs of progress have been made in the last few years, there are still research gaps regarding the effects of short-term and long-term exposure to e-vapors. However, the evidence gathered so far clearly indicates that vaping affects the periodontal ligament and fibroblasts and can be linked to serious health issues–like periodontitis and oral cancer. It is important to understand the mechanisms behind the toxicity of electronic cigarettes and how different variables (eq. the chemical composition of e-liquids) can influence the outcome. The different compositions of the tens of thousands of e-liquids can affect the experimental results and it is also difficult to quantify e-cigarette exposure.

Future research should focus on robust-designed studies, especially in vivo studies, in order to obtain conclusive results and strong evidence for the impact of e-cigarettes on periodontal and oral cancer initiation and progression. Quality scientific information is vital for the introduction of standardized regulations of these products. Additionally, it is essential to determine to what extend vaping can influence the success of chemotherapy and in cancer patients.

Prosthetic treatment should not be seen only as restoring the continuity of the dental arches and rehabilitating the functions of the dento-maxillary system, but must be approached holistically, taking into account the oral status, in correlation with the other loco-regional and general factors

2. IMPACT OF THE DESIGN AND MATERIALS USED FOR FIXED PROSTHETIC CONSTRUCTIONS ON ORAL STATUS

Introduction

In a digital workflow, the final device realization through the computer-aided manufacturing (CAM) process can be subtractive or additive. The subtractive method involves milling a monolithic block or disk of a certain material.

In the additive procedures, such as fused deposition, stereo-lithography, or inject printing, the material is deposited layer by layer to generate the final 3D shape. Currently, 3D-printing has evolved with a wide variety of polymeric materials in order to obtain prosthetic constructions with optimal characteristics (Miura et al., 2019, Ruse et al., 2014).

Our studies aims at a comparative analysis of three types of materials that are used for provisional crowns/bridges realization: Superpont C + B (SpofaDental, Jicin, Czech Republic), heat-curing acrylic resin, Zotion dental milling PMMA block (Zotion, Chongqing, China), Freeprint Temp (Detax GmbH & Co. KG, Ettlingen, Germany) resin. In our studies, the attention was focused on the analysis of surface roughness before and after finishing and polishing, and the mechanical strength of these materials, following whether there is a significant difference between the devices that were obtained by conventional technology, which uses heat curing resins and the samples that were obtained by subtractive and additive digital technologies. A dental prosthesis is an artificial substitute, which has the role of reestablishing the dental arch interrupted by edentation and restoring the functions of the dento-maxillary system. Furthermore, it is a biological infrastructure with the role of support and aggregation for prosthetic construction. Therefore, when analyzing the longevity of a prosthetic appliance, we must follow the two structural elements equally, which respond differently to demands and have different behaviors over time (Kawala et al., 2018).

The treatment solutions for a single-tooth edentation are multiple and can be chosen according to several criteria: esthetics, mechanical resistance, the degree of teeth damage and, last, but not least, the patients' wishes. Possible treatment options in this situation can be metal–ceramic, all-ceramic, direct or indirect fiber-reinforced composite fixed dental prostheses, minimally invasive dental bridges or implants (Wieckiewicz et al., 2014).

Restorative dentistry is a particular segment of the biomaterials domain, due to the extremely large variety of materials used and, equally, to the challenges they are expected to face. Oral environment exposure requires dental materials which could withstand to an environment characterized by moisture and heat, acids and digestive enzymes attacks, impermeable for dyes, as well as aesthetic. Also, materials should be non-toxic, affordable, easily manipulated by the clinician, with a proper thermal expansion and thermal conductivity adequate to dental tissues, for not causing discomfort to the patient.

Materials subjected to mechanical forces should maintain their mechanical properties (fatigue resistance and wear resistance) when faced oral functionality. The wide range of materials available for restorative dentistry requires a good knowledge on their mechanical characteristics and provides the opportunity for multiple and diverse lines of research.

Posterior fixed partial dentures have different biomechanical behavior according to the restorative materials used. For example, some authors report that acrylic resin fixed prosthetic restorations can lessen the stress level in the connector region, and resin composite dental bridges can diminish the magnitude of stress on the layer of cement (Campaner et al., 2021).

The main goal of prosthetic treatments is to preserve the dental tissues to the maximum and the choice of retainer crowns must follow this conservative principle. Inlay-retained fixed dental prostheses may indicate when adjacent teeth have been previously restored and when implant placement is not possible or not indicated. Inlay- retained bridges are also a good option in patients with good oral hygiene and low susceptibility to caries, with a minimum coronal tooth height of 5 mm, parallel abutments, and a maximum mesio-distal edentulous space of 12 mm.

Contraindications include severe dental mal-positions, the absence of enamel on the preparation margins, extensive crown defects and mobility of abutment-teeth (Monaco et al., 2012, August et al., 2014). A particularly important aspect that influences the clinical longevity of the minimally invasive bridges is mechanical resistance. This parameter depends on the dental materials used, design, and developing tensions, both at the bridge elements and at the abutment teeth (Rezaei et al., 2011).

Inlay retained bridges are highly appreciated in the prosthodontic clinical practice since they are minimally invasive for the biological support tissues. However, from a biomechanical perspective, it is not clear whether they are as reliable as other therapeutic options. Moreover, it is not clear whether the stress determined by the loading force can cause damage to the prosthetic device or to the abutment teeth, thus influencing the longevity of this restoration. Because testing biomechanical parameters is not possible in the oral cavity without affecting the integrity of hard and soft tissues, the finite element method (FEM) is a useful way to appreciate the strengths and weaknesses of a prosthetic device and the stress induced into the dental support in various circumstances (Bandela et al ., 2020).

Considering all this and the multitude of design possibilities of the prosthetic appliance and possible materials available for the restoration, further studies are needed to clarify the indications and limitations of fixed dental bridges to maximize treatment outcome. Finite element analysis is a method that has as a main objective the modeling and description of mechanical behavior of elements with complex geometry, with the added advantage of the simplicity of basic concepts; the mathematical model thus realized includes certain working hypotheses, simplifications and generalizations (Diaconu et al., 2014). To evaluate the stability of dental bridges and the stress they exert on the abutment teeth under conditions of variable masticatory demands, a working hypothesis can be simulated in the situation of a reduced partial edentation

Our studies aims to analyze stress levels at a three-element dental bridge, with inlays used as retainers to evaluate tension levels on abutment teeth and analyze the maximum tensions applied to abutment teeth and the dental prosthesis, considering the dynamic action of masticatory forces. For this purpose, we used finite element analysis, a method that provides an image of the distribution of forces, both at the artificial substitute and the biological support level (Smielak et al., 2016).

There were numerous ways and attempts of experimental research, but due to the complexity of dental structures, composed of various tissue materials mechanically and chemically interconnected, and due to complex tooth morphology and surrounding structures, these attempts failed to obtain precise and reliable results (Lin et al., 2005) A successful prosthetic therapy depends on the patient's oral health status and, on the biological and biomechanical requirements of the bridge, on the materials chosen and the alimentary behavior (food consistency).

The finite element analysis (FEA) is a significant tool for biomechanical analyses in biological research. It is an ultimate method for modeling complex structures and analyzing their mechanical properties. FEA is widely accepted as a non-invasive and excellent tool for studying the biomechanics and the influence of mechanical forces on the biological systems (Trivedi S et al., 2014). Since it is fairly difficult to conduct an in vivo or in vitro assessment of the forces acting during mastication, the finite element analysis is preferred as, if the modeling is accurate, it may provide very useful information on the stresses (Diaconu et al., 2014, Tanculescu et al., 2017).

The type, arrangement and total number of elements impact the accuracy of the results (Viceconti et al., 2007, Van Staden et al., 2006, Diaconu et al., 2016). The steps followed are generally constructing a finite element model, followed by specifying appropriate material properties, loading and boundary conditions so that the desired settings can be accurately simulated.

The results of the possibilities of evaluation and treatment regarding prosthetic therapy are illustrated by the following publications:

1. Mârtu I, A Murariu A, Elena Raluca Baciu, Carmen Nicoleta Savin, Iolanda Foia , Monica Tatarciuc, **Diaconu-Popa D**. An Interdisciplinary Study regarding the Characteristics of Dental Resins Used for Temporary Bridges, *Medicina* 2022, 58, 811. https://doi.org/10.3390/medicina58060811. IF 2,948.
2.Diaconu-Popa D, Vițalariu A, Matei D, Matei A, Monica Tatarciuc M. Digital technologies in fixed prostheses , *Romanian Journal of Medical and Dental Education*, Vol. 10, No. 1, 2021, p.113-122
3. Tatarciuc M, Maftei GA, Vitalariu A, Luchian I, Martu I, **Diaconu-Popa D.** Inlay-Retained Dental Bridges—A Finite Element Analysis, *Appl. Sci*. 2021, 11, 3770, 1-17, https://doi.org/10.3390/app11093770
4. Tatarciuc M, Vitalariu A, Luca O, Aungurencei A, Aungurencei O, **Diaconu-Popa D**. The influence of food consistency on the abutment teeth in fixed prostheses a fea study, *Rev.chim.(Buchares) t*2018*)* 69, 2, p. 407
5. Viţalariu A, Tatarciuc M, Cotaie GH, **Diaconu D.** In vitro testing – an esential method for evaluating the performance of dental materials and devices, *International journal of medical dentistry*, volume 5, issue 2, april / june 2015 http://www.ijmd.ro/index.php?link=articole&anul=2015&nr=2&vol=19#a1

Materials and methods

For analyzing the characteristics of dental resins used for temporary bridges it was realized 60 samples, 30 for the tensile tests and 30 the surface roughness analysis (fig 66).

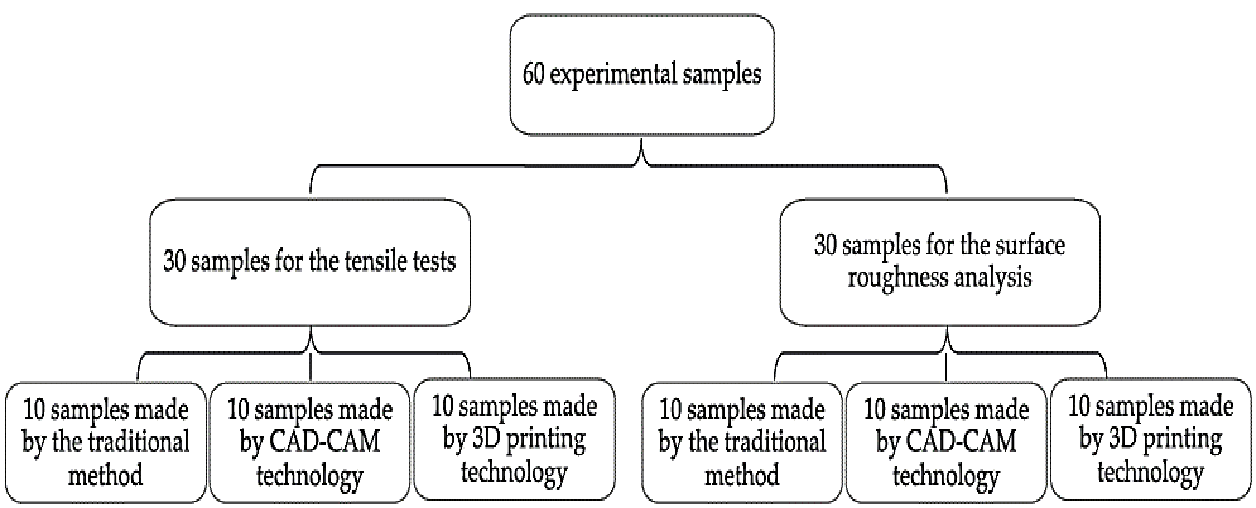


Fig.66 Experimental samples. CAD: Computer-aided design; CAM computer-aided manufacturing

A total of 20 samples were made by the traditional method, using the heat-curing acrylic resin Superpont C + B (SpofaDental, Jicin, Czech Republic); 20 were performed by subtractive CAD-CAM technology, using Zotion dental milling PMMA block (Zotion, Chongqing, China); and 20 by additive digital technology, using Freeprint Temp (Detax GmbH & Co. KG, Ettlingen, Germany) resin.

The first step was to make two different shapes of wax patterns. For the traction tests, the wax patterns measured 2 mm thickness with dumbbell-shaped wax patterns with following dimensions: 75 mm length, 12.5 mm width at the extremities, and 4 mm in the central area. For the roughness tests, the wax patterns were a rectangular shape, also 2 mm thick, 70 mm length, and 30 mm width.

The dimensions chosen were in accordance with ASTM D-638 (and ISO 527-2 standards) and were adapted to the requirements of the device that was used in the analysis of the mechanical characteristics.

For the analysis of the surface condition, the sample sizes were also chosen according to the standards that were imposed by the roughness tester that was used. For conventional resin samples the wax patterns, made of pink wax, 2 mm thick (DistriWax-DinstridentPlus, Suceava, Romania) were transformed into acrylic specimens according to the same technology that is used for temporary acrylic dental bridges. They were first invested in dental stone (Elite Rock class IV gypsum-Zhermack, Badia Polesine, Italy) in order to obtain a mold (fig.67)

After the mold isolation with a separating agent (Isodent/Spofa Dental), the acrylic resin was prepared, following the producers indications: mix 2 g of powder with 1 gram of liquid (or in units of volume 3 parts powder to 1 part liquid), the mixing time being 1.5 minutes.

When the resin has a plastic consistency, it is introduced into the mold, and pressed with the help of the hydraulic press. The curing process is performed in a thermo-polymerization chamber, at a temperature of 100°C, pressure 2-4 bar, for 40 minutes.

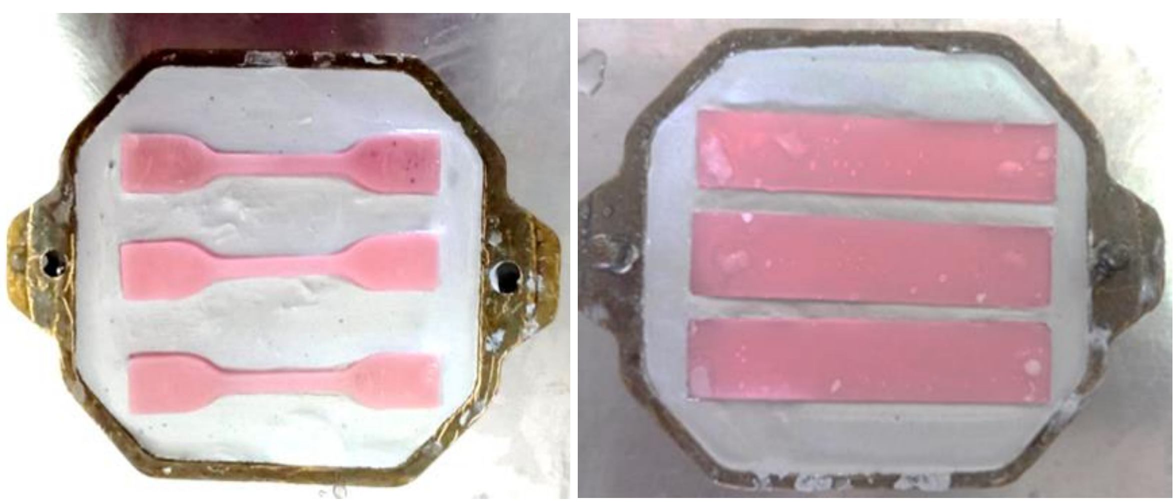


Fig. 67 Investing wax pattern and mold realization

After cooling, the samples were remove from the mold (fig.68), sandblasted, finished and polished, on one side, using specific tools for acrylic bridges.

Fig.68 Divesting resin samples

Digital samples was realized in a private practice dental laboratory (Draghici Dental). For the subtractive method, the milling system with 5 Axes K5 + VHF was used; the wax pattern were initially scanned in order to obtain their virtual image using the scanning and modeling EXOCAD system (fig.69).

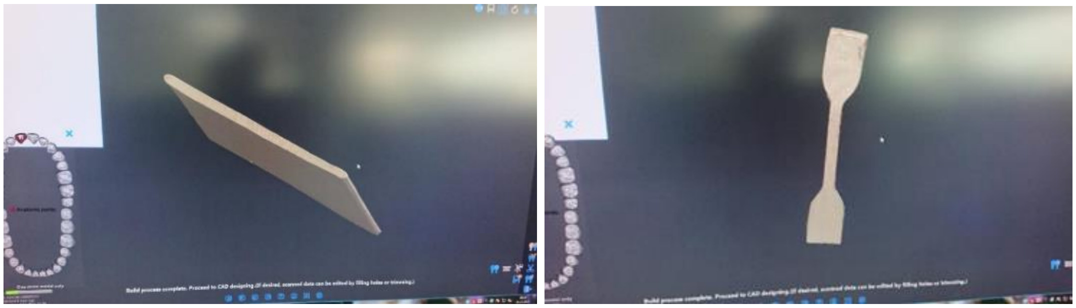


Fig.69 Wax patterns scanning

A large disc of PMMA A1 monochrome acrylic resin was chosen, with a diameter of 98 mm and a thickness of 20 mm, used for temporary long-term crowns or bridges. The disc was fixed on the plate of the milling machine, and based on the information transmitted by the CAD unit, the two types of samples were performed. The samples were finished and polished as those performed by the conventional method, also on a single surface (fig.70).

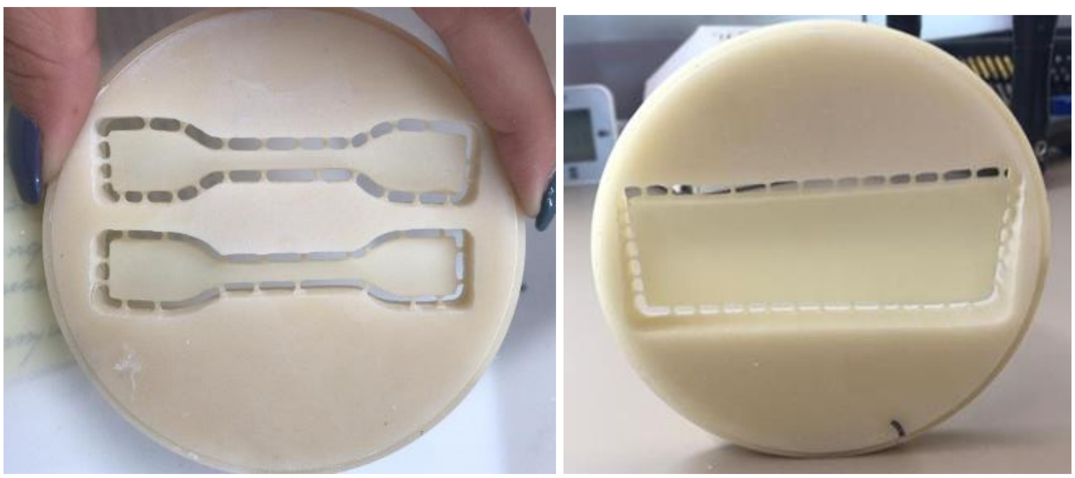


Fig.70 Sample milling and finishing

For the additive technology, data on the shape and size of the wax patterns were acquired using the same scanning system and then the information were transmitted to the Asiga MAX 3D printer (fig.71). The resin used for the printing method was LCD / DLP 3DM CB.

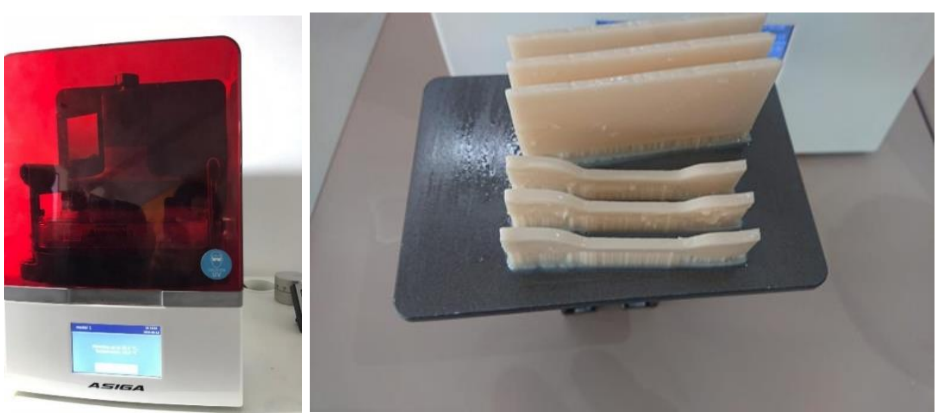


Fig 71 3D Printing specimens

The samples were processed following the protocol used for the other two types of specimens.

The mechanical tests were performed in collaboration with Gheorghe Asachi Technical University of Iaşi, Faculty of Materials Science and Engineering. Tensile tests were carried out at room temperature, according to the ISO 527-1: 2000 standard, using a computer-controlled testing machine, with a dynamic clip-on strain gauge extensometer (Instron 2620-601) for direct strain measurement. The rectangular specimens were placed and fixed between the grips of the testing machine (fig. 72).

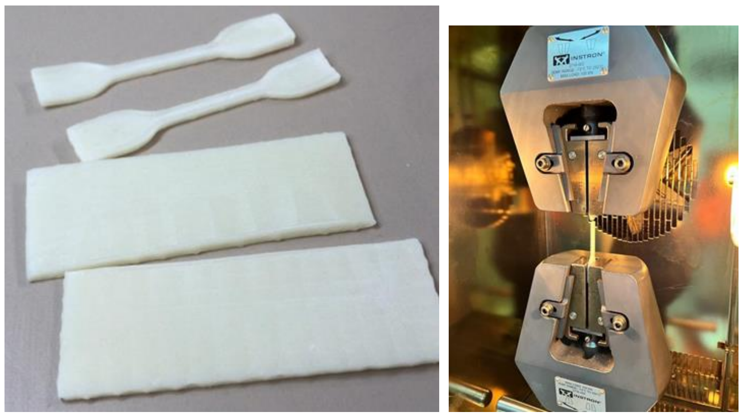


Fig.72 Samples and Instron testing machine

The tensile load was applied at a crosshead speed of 1 mm/min. Young's modulus (the slope of a secant line between 0.05% and 0.25% strain on a stress-strain plot), tensile yield (tensile stress at yield) and tensile strength (maximum tensile stress during the test) were determined. To determine the surface roughness, the Ra, Rz and Rq parameters were recorded for each sample. Ra represents the arithmetical mean of the absolute values of the profile deviations from the mean line of the roughness, Rz is the average of all values represented by the maximum height between the maximum and the minimum profile within the assessment length, for each sample and Rq represent the root mean square of the surface roughness.. Three roughness measurements were made on the surface of each sample and the data was recorded with Form Talysurf roughness tester (Taylor Hobson, England), whose peak radius of the cantilever is r = 2 μm (fig.73).


Fig.73 Roughness registration

The statistical analyses were employed using Stata 16.1 software (StataCorp, College Station, TX, USA). The two-way ANOVA analysis for the two paired samples, before and after the finishing and polishing procedures.For the finite element analysis (FEA) of of the stresses induced by a minimally invasive bridge - an inlay retained bridge a description of the geometric model and finite element modeling was first performed; this step includes modeling of material characteristics, choosing the finite elements and introducing properties, generating the finite element structure, introduction of limit conditions and forces. Analysis and solution of the finite element model involved setting the solving parameters and then visualizing the states and variations of the parameters. Images of molars, canines, premolars and incisors were taken as a reference; their dimensions were made on a scale, according to the dimensions of the molars on computed tomography (CT) images. Based on the mandibular model, the absence of tooth 3.5 was simulated. To simplify the finite element analysis, only the dental elements 3.3, 3.4, 3.6 and 3.7 were preserved from the assembly. For the application of optimal forces to simulate physiological masticatory load, the main muscles of the mastication process, the masseter muscles and lateral and medial pterygoid muscles were taken into account (fig.74)

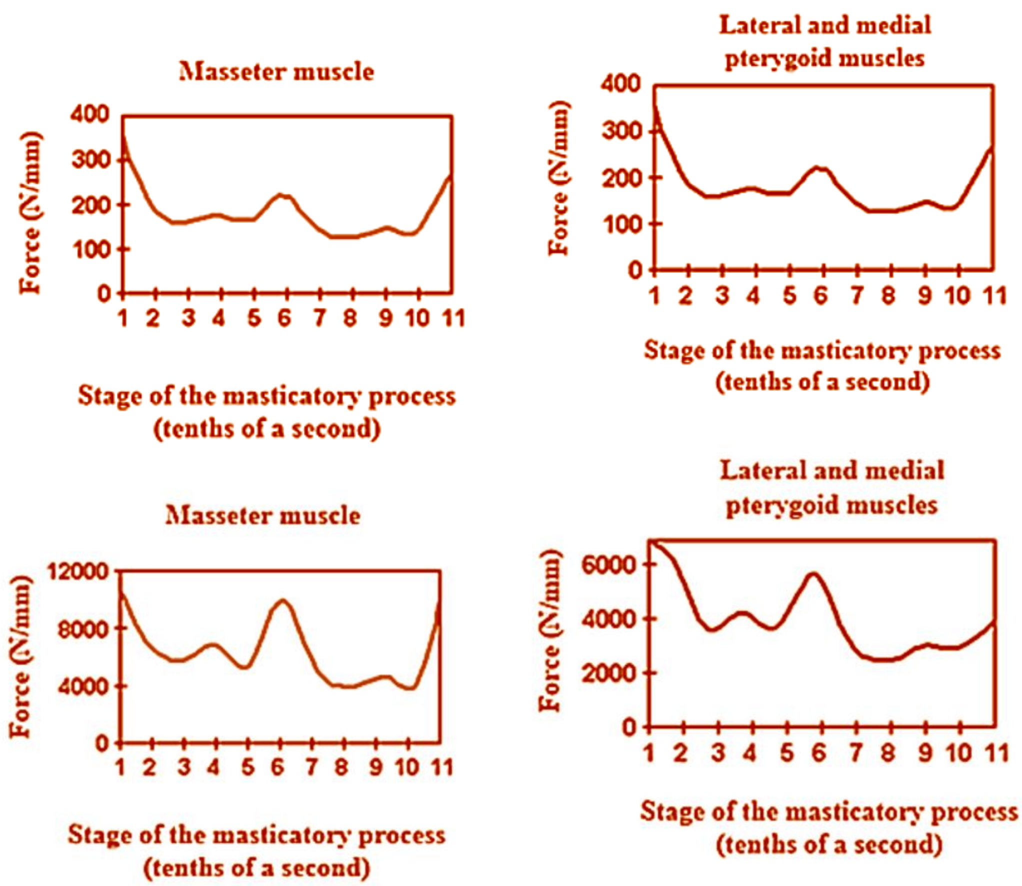


Fig.74 Variation of forces and moments developed by the masseter pterygoid muscles during the masticatory process (a mastication cycle).

The average values of masticatory forces vary from individual to individual and are also influenced by food consistency. In this study, we applied an average force value of 220 N in the premolar area and 400 N in the molar area, introduced in the Autodesk Simulation Mechanical 2014 program (2014, San Rafael, California, US). The model was subjected to loading with a vertical force, applied, in turn, on the occlusal surfaces of each element of the dental bridge: both retainers and pontic. The modeling of an inlay-retained dental bridge was performed, with retainers on teeth 3.4 and 3.6 and pontic on 3.5 (fig.75). The material used for the bridge was a titanium alloy (Ti6Al4V) (Dentaurum, Germany)

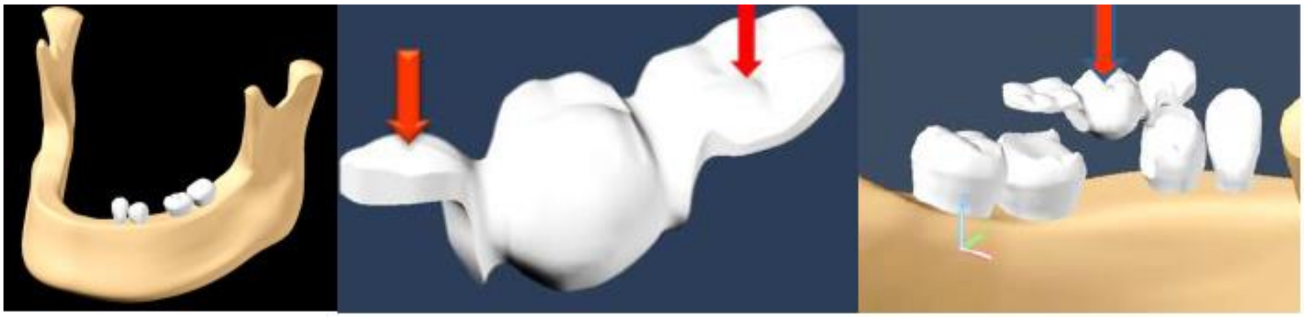


Fig.75 Models of the mandible and the bridge

The force was applied first in the contact area of the occlusal surface of the inlay at the level of 3.4, then at the occlusal face of 3.6 and then on 3.5, occlusal surface, simulating the pressure induced by the food fragment during the masticatory act.

FEM analysis consists of a mesh realization by splitting a solid volume into finite elements of parallelepiped or tetrahedron shape. Each element behaves individually, with the same characteristics as the base material. Depending on the pressure applied to every element, a specific load or temperature will be exerted and transmitted to the adjacent elements through nodes. For an enhanced accuracy of results, a condition was imposed for the mesh realization: the length between two nodes must always be the same. The model was exported to Autodesk Simulation Mechanical 2014 with a file ending in *. * Sat. These files are opened one by one in Autodesk Simulation Mechanical 2014. After determining the type of analysis (static stress), the mesh command was given. Depending on the objectives of the analysis, the used material properties were: modulus of elasticity, Poisson's ratio and density (table XXI)

Table XXI Material characteristics for each element of the structure subjected to finite element analysis

Element	Modulus of Elasticity (MPa)	Poisson's Ratio	Density (kg/m^3)
Bone	13,800	0.30	1450
Dentine	18,600	0.31	1900
Ti6Al4V alloy	110,000	0.40	4381

We analyzed the tensions induced as a result of the application of these forces, on each element of the bridge, in the contact areas located between retainers and pontic and also on abutment teeth.

For the area where the bridge is in contact with the food fragment, during mastication, it is considered that there is no degree of freedom, and restrictions will be placed for all six movements. In Autodesk Simulation Mechanical 2014, these types of supports are represented by triangles.

To analyzing the influence of food consistency on the abutment teeth in fixed prostheses the modeling was done starting from the hypothesis that the dental elements are deformable structures under the action of various variable demands such as intensity, application point. A finite element model representing a single tooth gap in the lateral left mandible, represented by the second premolar was created. The first premolar and first molar served as abutment teeth. The missing premolar was replaced by one unit pontic. The 3D images of the bridge with full crowns as retainers were obtained using a contact scanner and computer aided design (CAD) system (fig.76).

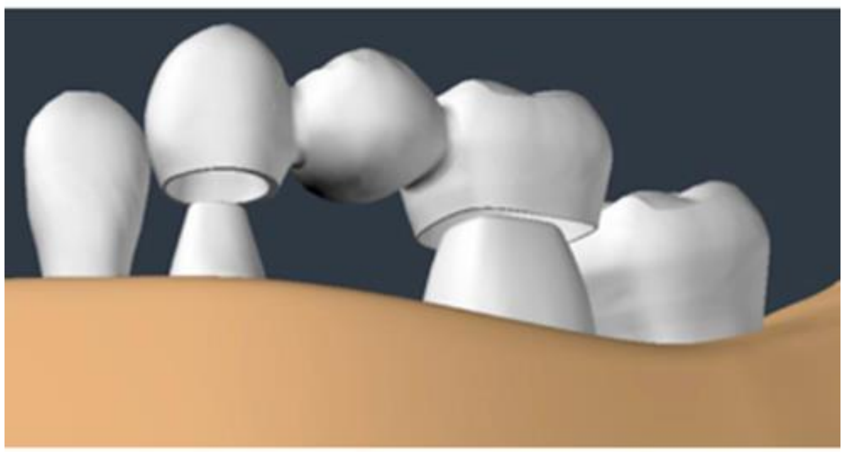
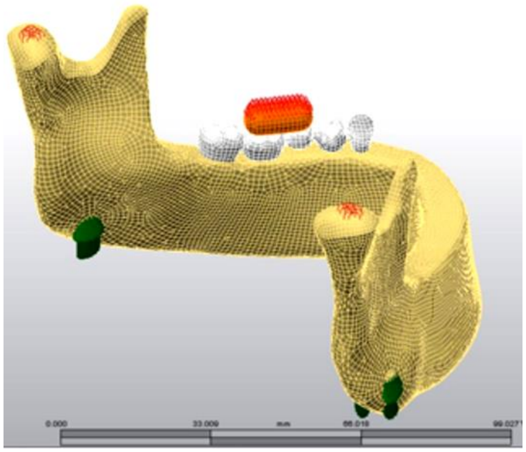


Fig.76 Model of the dental bridge and model of the bridge with full crowns on the abutments

Each element behaves as an entity with the same characteristics as the base material. After the type of finite element was chosen the discretization can be done manually or through a program. In our study the Autodesk Simulation Mechanical 2014 was used to perform the model. Load application considered the maximum force developed by the masseter and pterygoid muscles. The action of the forces developed by the manducatory muscles during mastication produces reaction forces in the temporomandibular joint and on the contact area between occlusal surfaces and the food. Depending on the loading on an element, it will support a certain stress and transmit it to the neighboring elements through the nodes. Although, the muscle activity and craniofacial morphology affect the occlusal load in actual clinical situation, it is difficult to simulate individual muscle forces to FEA modeling. So, usually vertical or oblique load on the teeth is used as an input load in FEA. The model is exported to Autodesk and after determining the type of static stress, the mesh command is given. Absolute mesh size and absolute mesh dimension are set to 1mm for the purpose of an accurate analysis. In order to get accurate results with the finite element analysis, the loads should be similar to the physiological ones. Stress levels were calculated according to the Von Mises criteria for each node. The geometry of the healthy standard tooth as abutment has been taken from literature.

The prepared surfaces of the abutments were: 14.015 mm2 for premolar and 17.56 mm2 for the molar (fig.77, fig.78).



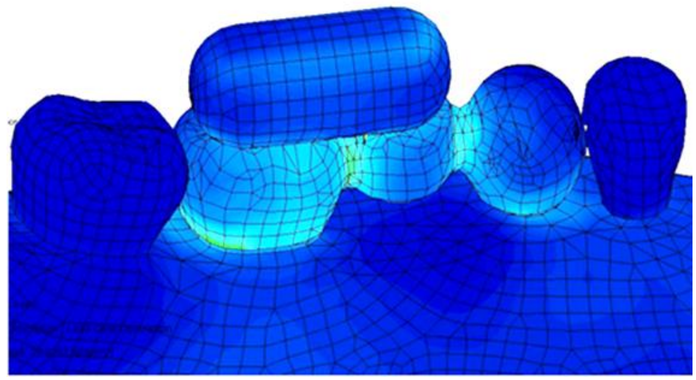


Fig.77. Model of the mandible with the bolus applied on the bridge

Fig.78 Model of the mandible with the bolus applied on the pontic and abutment 3.6

A more realistic modeling situation is the one in which a deformable food fragment is applied on the bridge, thus lowering the direct loading exerted on the dental bridge and, implicitly, on the abutment teeth. We surveyed the stress induced by different food consistency with elasticity modulus between 0 MPa and 20000 MPa. Every finite element was ascribed with the biomechanical characteristics of the component represented by the group (Modulus of elasticity, Poisson's ratio).

The differences in elastic modulus are believed to affect the clinical performance of the bridge. All the materials were assumed to be isotropic, homogeneous, and linear elastic. For the bridge it was chosen a titanium, alloy due to its high biocompatibility and biomechanical behavior. The properties of materials used into the simulation were adopted from those available in the literature (table XXII)

Table XXII Properties of the materials used in the study

Element	Elasticity modulus [MPa}	Poisson modulus	Density [kgm/^{3}]
Bone	**13800**	**0.30**	**1450**
Dentine	**17600**	**0.25**	**1900**
Ti6Al4V	**110000**	**0.40**	**4381.7**

Oral rehabilitation is inherently difficult, due to the functional and parafunctional forces within the mouth that result in extremely complex structural responses by the oral tissue. The applied forces for this simulation were F= 400-800 N (on the molar), F= 220-450 N (on the premolar).

The force value was increased every 100 MPa for each determination and the maximum value in abutments was recorded. Loading conditions were vertical and distributed on a15 degrees to the vertical and concentrated. The principal stresses were calculated and compared for the retainers (first molar and first premolar) and pontic (second premolar).

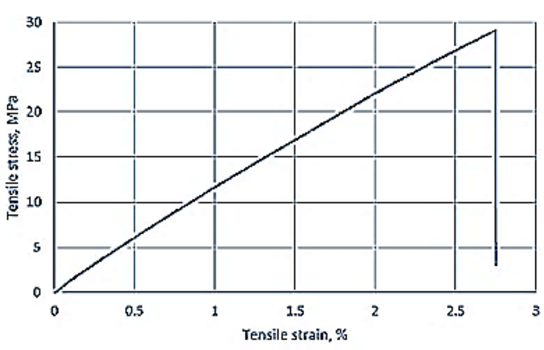
Results

To analyse the characteristics of the resins used for temporary bridges tensile stress and tensile strain were calculated for the three categories of samples and the diagrams (fig. 79) illustrate that the best resistance to fracture load has been registered for the milled samples, followed by the heat-cured samples. The lowest value of mechanical resistance was found for the 3D-printed specimens. The tensile behavior of the materials was similar, observing a reversible stage of elastic deformation, followed by an irreversible plastic deformation up to the maximum limit when material fracture occurs.

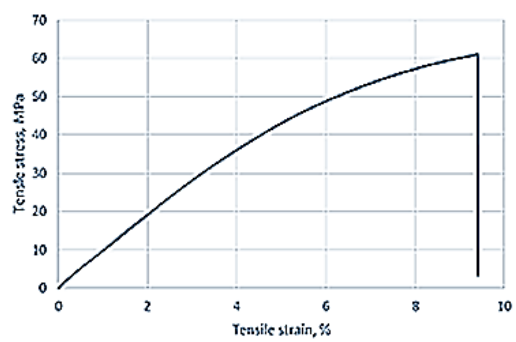
In our study, following the statistical analysis of the results, it can be seen that statistically speaking there are no significant differences between the values of mechanical strength parameters. As such, temporary bridges that are made by digital methods are not significantly different in terms of fracture strength, of those that are performed by conventional methods.

Roughness is an important characteristic of surface quality and can be assessed by determining the micrometric profile of the finished and polished samples. Surface roughness is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough and if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

a

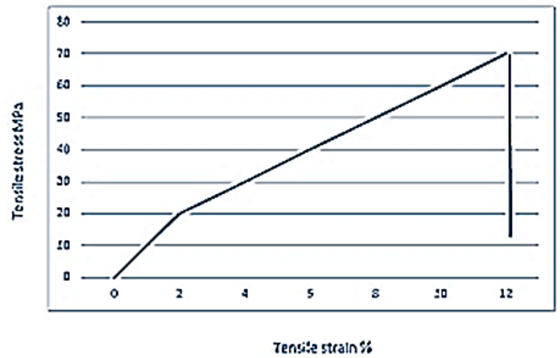


F_{max}, N	E, Mpa	$R_{p0.2}$, Mpa	R_m, MPa	Au, %
310.84	1239.31	27.93	28.83	2.76



b

F_{max}, N	E, Mpa	$R_{p0.2}$, Mpa	R_m, MPa	Au, %
630.14	1035.17	35.34	60.98	9.38



c

F_{max}, N	E, Mpa	$R_{p0.2}$, Mpa	R_m, MPa	Au, %
520.14	987.17	35.34	40.93	6.37

Fig.79 Tensile tests vs. tensile strain diagrams: (a) Milled samples; (b) 3D printed samples; (c) Cured sample

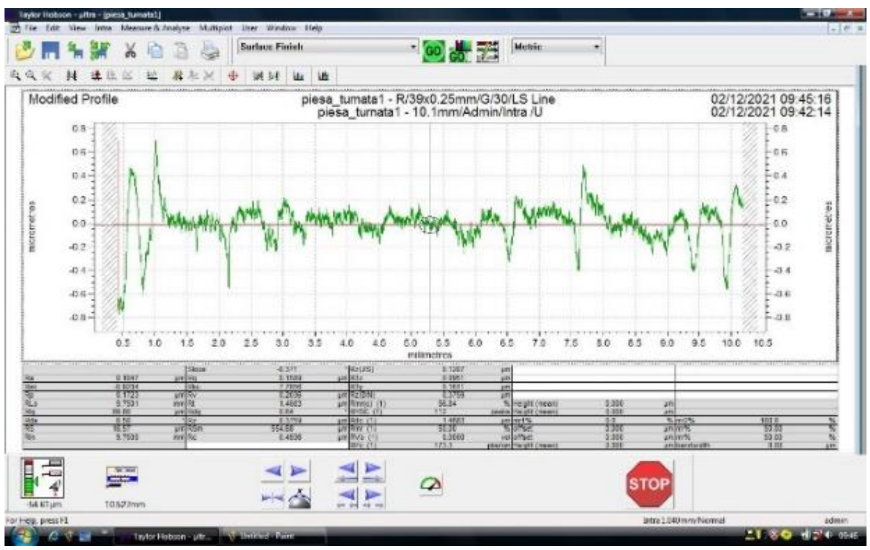
In our study, following the statistical analysis of the results it can be seen that there are no significant statistically differences between the values of mechanical strength parameters. So temporary bridges made by digital methods are not significantly different, in terms of fracture strength, of those performed by conventional methods.

Roughness is an important characteristic of surface quality and can be assessed by determining the micrometric profile of the finished and polished samples. Surface roughness is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough and if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface.

However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose. The shape and dimensions of the micrometric profile have an influence on the adherence and development of the bacterial biofilm at the surfaces of the acrylic prostheses. Roughness diagrams were recorded and subsequently analyzed, following comparative surface parameters (fig.80).

Milled samples

3D printed samples



Heat-cured samples

Fig.80 Roughness diagrams

The values recorded for the analysis of surface roughness were centralized in table XXIII, in order to compare the data and establish statistically significant differences.

To materialize even more eloquently the differences of the parameters that characterize the surface condition of the three categories of materials, we calculated the average values of roughness parameters before and after finishing and polishing.

The graphic shows a significant difference in the roughness parameters, for all three categories of samples, which once again demonstrates the importance of rigorous surface processing and compliance with the working protocol, both in terms of stages and instruments. (fig.81).

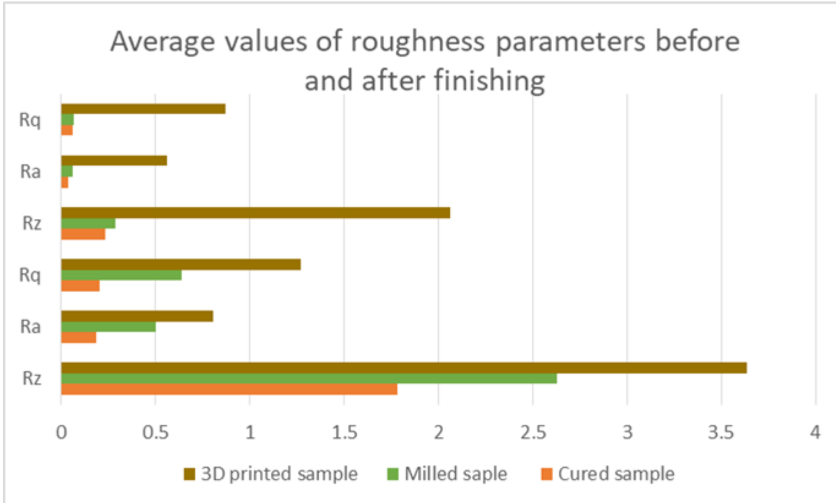


Fig.81 Average values of the surface parameters

In order to compare the variations of the roughness parameters, a statistical analysis of them was performe Taking into account the Ra and Rz coefficients by each of the three techniques, we may say that all the three techniques generated an increase in both Ra and Rz coefficients. Whilst, the Ra coefficient decreased on average by 66%, the Rz coefficient decreased by 47%. Zooming in into the data for each of the three techniques, it seems that the CAD-CAM method managed to reduce the highest reduction on Ra coefficients by about 97%. When it comes to the Rz coefficient, the largest reduction was also induced by the CAD/CAM milling technology (about 88 percent**).** At the other end lies the 3 D Printing method which only reduced the Ra and Rz coefficients by about a third. (table XXIII)

Table XXIII Variation of Ra and Rz coefficients after the treatment (%)

Method	**Mean Ra coefficient**	**Mean Rz coefficient**
Milled resin	**-97.40**	**-88.44**
Conventional resin	**-75.56**	**-17.77**
Printed resin	**-29.50**	**-35.34**
Total	**-66.34**	**-47.18**

To materialize even more eloquently the differences of the parameters that characterize the surface condition of the three categories of materials, a two way-ANOVA analysis was carried out. In order to check the robustness of our results, the analysis was performed for each of the three rugosity measurements.

The normality of data for each sample by treatment, material used, and rugosity measure was initially tested in order to make sure the series were normally distributed. Finally, post hoc multiple comparisons were performed using Tukey's test. table XXIV summarizes the results of the two-way ANOVA analysis that was employed on a sample of 30 observations, 10 for each of the materials that was used. The results revealed that surface roughness was significantly influenced by both the type of resin that was used ($p < 0.001$) and the treatment induced by finishing and polishing ($p < 0.001$). Similar p-values were obtained for each of the three resins.

Table XXIV Means (SEM) of surface roughness parameters by resin thatwas used before and after polishing

Surface Roughness	3D Printed			Milled			Heat Cured		
	Baseline	After Polishing	ΔR%	Baseline	After Polishing	ΔR%	Baseline	After Polishing	ΔR%
R_a	0.80(0.02) [a]	0.56(0.02) [b]	−15.10	0.55(0.04) [b]	0.06(0.00) [d]	−44.61	0.17(0.02) [c]	0.04(0.00) [d]	−38.78
R_z	3.26(0.12) [a]	2.08(0.04) [c]	−18.07	2.51(0.13) [b]	0.32(0.03) [d]	−43.73	0.31(0.02) [d]	0.24(0.01) [d]	−10.28
R_q	1.26(0.04) [a]	0.86(0.02) [b]	−15.75	0.64(0.04) [c]	0.07(0.00) [d]	−44.60	0.13(0.00) [d]	0.06(0.00) [d]	−26.51

Note: n = 10 obs. per sample a–d Means in a row without a common superscript letter are different ($p < 0.05$) as evidenced by two-way ANOVA and the Tukey's test. Ra: arithmetical mean of the absolute values of the profile deviations from the mean line of the roughness; Rz: average of all values that are represented by the maximum height between the maximum and the minimum profile within the assessment length; Rq: the root mean square of the surface roughness

It is important to note that there was also a significant interaction between the type of resin that was used and the polishing treatment on the coefficients assessing the surface roughness (Ra: $F(df\ 2, 54) = 41.46$, $p < 0.001$; Rz: $F(df\ 2, 54) = 97.32$, $p < 0.001$ Rq: $F(df\ 2, 54) = 55.82$, $p < 0.001$).

Computing the mean comparison test for paired samples confirms that there is a significant differences between the mean of the sample before the treatment and the mean of the pair sample after the treatment. Thus, we strongly reject the null hypothesis claiming that the means are equal in all the cases. No matter if we look to the whole sample or to the samples by each of the three techniques, the treatment seems to have a significant impact and thus effect their mean.

Specifically, the results indicate that the treatment reduced both the Ra and Rz values and thus we reject the null hypothesis of equal means in favour of the alternative hypothesis of positive differences between before and after values. One also needs to notice that the only case where we cannot be 99% confident (but only 95%) of a difference is when looking on the Rz coefficient for the conventional method.

Plotting the samples for each of the groups also clearly displays that the treatment induced through the three methods reduced both the Ra and Rz values. The CAD-CAM milling method clearly determines the largest reduction of coefficients (fig. 82).

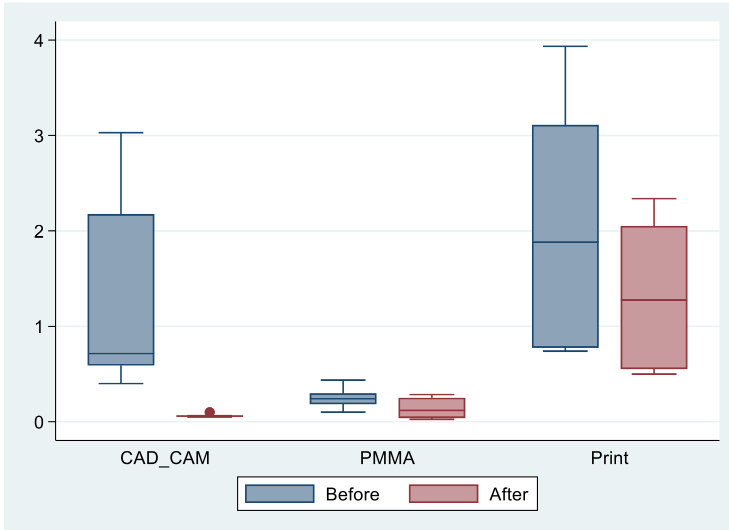


Fig 82. Box plot of both Ra and Rz values by method/technique

The results hold demonstated that the milling technology seems to generate the largest reduction by far (fig.832). However, it is interesting to note that while the reduction generated by the milling and heat-curing seems to be higher for the Ra coefficients (compared to the Rz), the 3 D Printing method induces a larger reduction in the Rz coeffcient. Results indicated significant decreases of both Ra and Rz coefficients for each of the three techniques employed (conventional resin, substractive method and additive technology). This is also emphasized by the blox plot graphs.

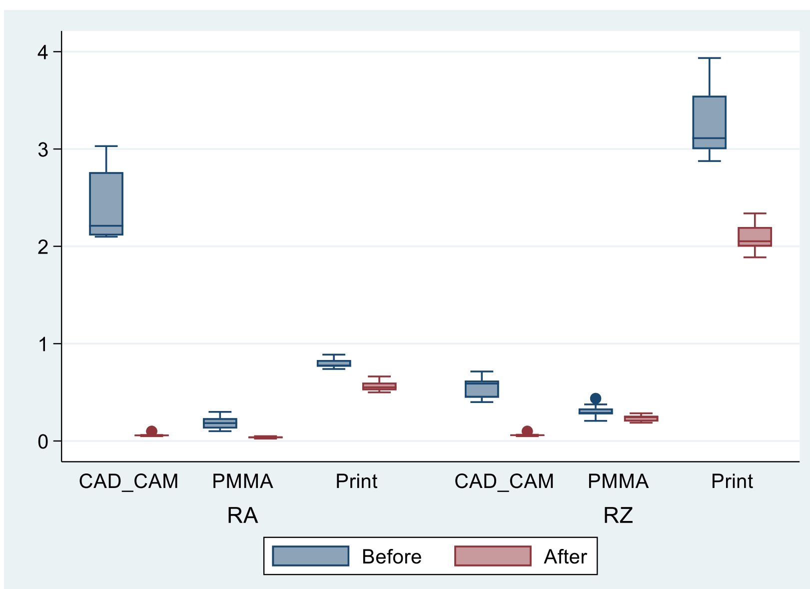


Fig. 183. Box plot of RA and RZ values by method/technique

The lowest values of roughness was observed at the milled samples, and the highest values are found in 3 D printed samples. For the heat-cured specimens there is a decrease of the Rz value, after processing, but not of the Ra value.

The small-amplitude prosthetic constructions can be made directly in the dental office and it was interesting to follow what is the stress of the abutment in the case of a minimally invasive bridge. The results of the finite element analysis follow, according to the determination of loads applied to each area of the dental bridge. First, the distribution of deviatoric stresses (von Mises tensions) at the pontic level was analyzed when the reaction force, which opposes the muscular force, is located in the area of the missing premolar, 3.5 (fig.84).

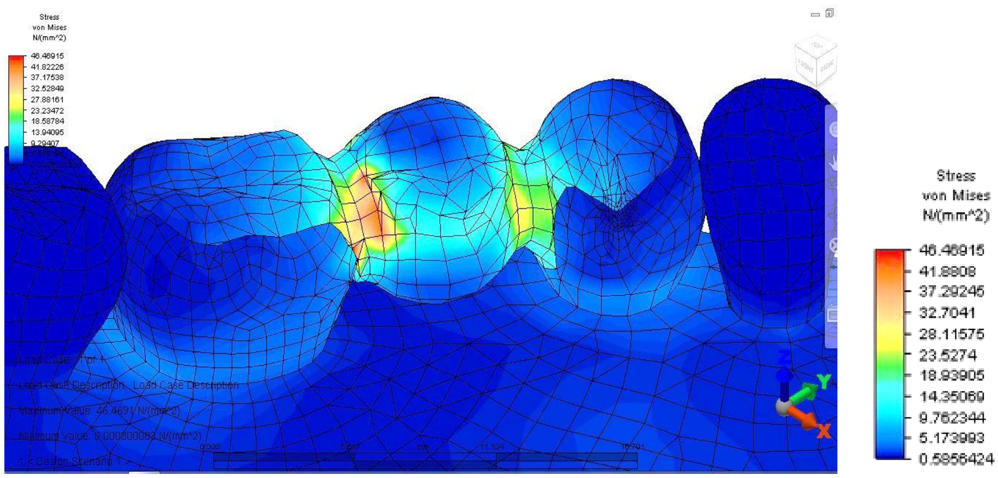
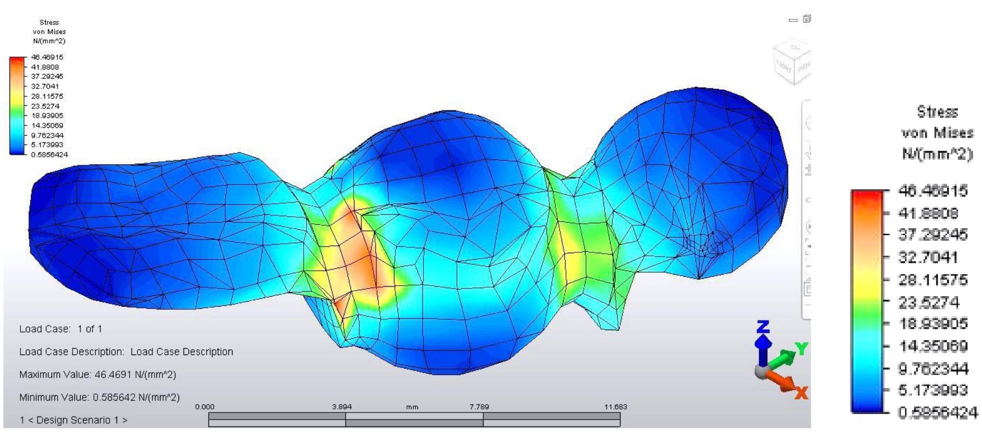


Fig.84 Tensions distribution at the bridge level, when the reaction force is placed in the 3.5 area

From the model, we observed a higher tension on the prosthetic construction at the margin between the bridge and abutments. This phenomenon is related to the difference between the higher modulus of elasticity of the bridge alloy and the modulus of elasticity of abutment teeth. Furthermore, higher tensions develop at the junction between the bridge elements, and the maximum value is 46,469 MPa, between molar 3.6 and premolar 3.5. This high value of stress is explained by the smaller surface of the junction area. When analyzing stress values on abutment teeth, respectively molar 3.6 and premolar 3.4, they have a maximum value in the cervical area of the junction between teeth and bridge: the value of 14.456 MPa is equally distributed on the two abutment teeth (Fig.85, fig.86).



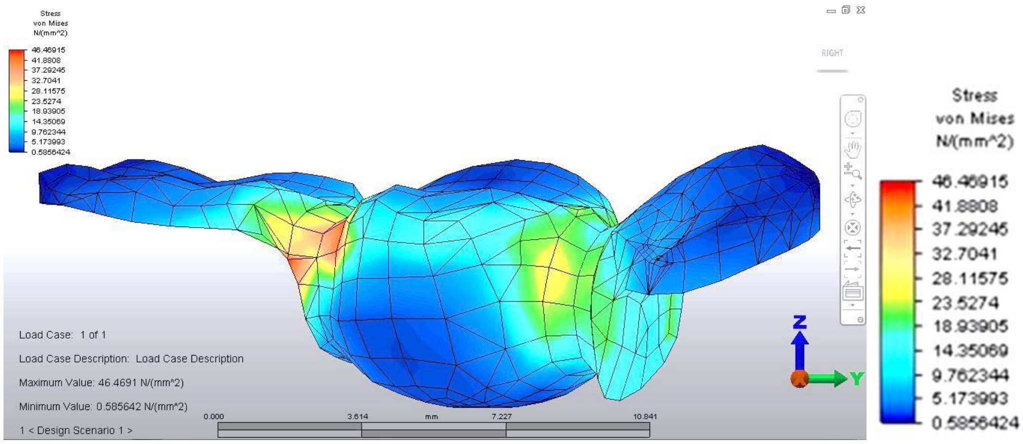


Fig.85 Tension distribution at the bridge level in three directions: axonometric, right and left, when the force is placed in the 3.5 are

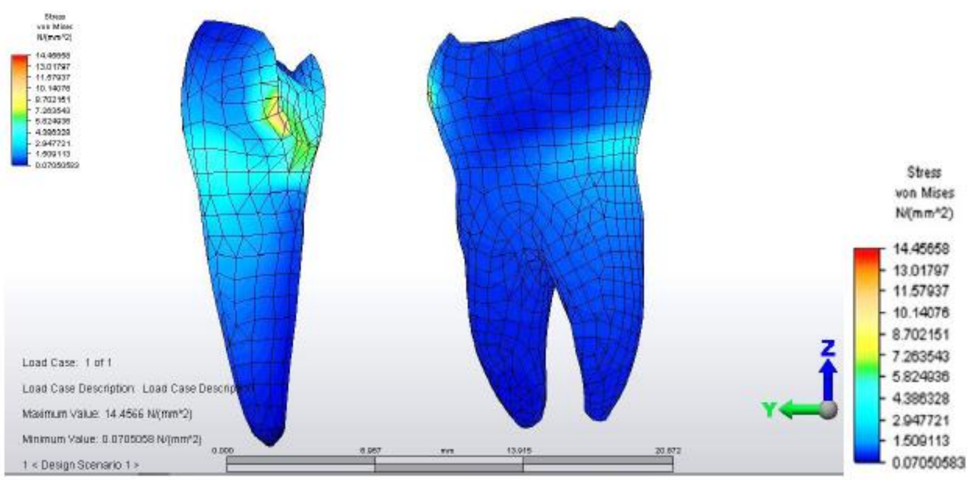


Figure 86. Tension distribution at the abutments level t when the force is placed d in the 3.5 area

Distribution of tensions at bridge level was then observed in the situation when the reaction force, which opposes the muscular force, is placed in the area of molar 3.6. This situation yielded a higher tension observed at the level of the bridge and at the mandibular bone level: the load is higher in the area of molar 3.6, where the reaction force is also applied.

The distribution of stresses at the level of the dental crown revealed that there is increased stress at the junction area between the pontic and the retainer, on molar 3.6; its value of 61.461 MPa, being 1.5 times higher than in the previous case.

Abutment teeth are subjected to a maximum tension of 15.054 MPa, the higher value being encountered in molar 3.6, both in the contact area with the bridge and in the area of contact with the mandibular bone, toward molar 3.7 (fig.87, fig.88).

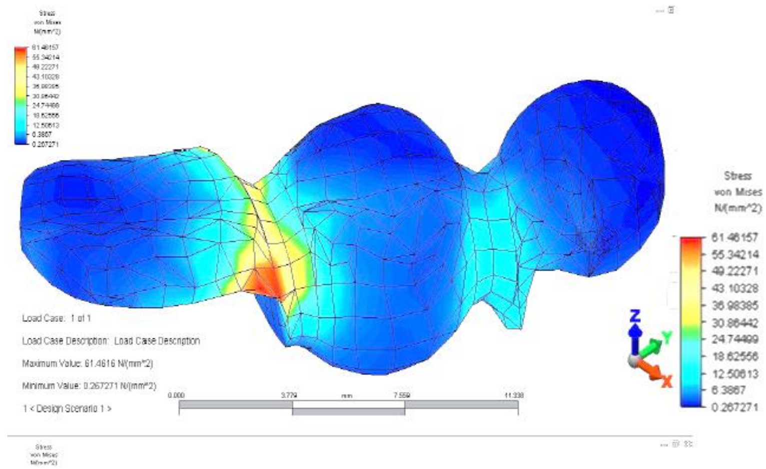


Fig.87 Tension distribution at the bridge level when the force is placed in the 3.6 area

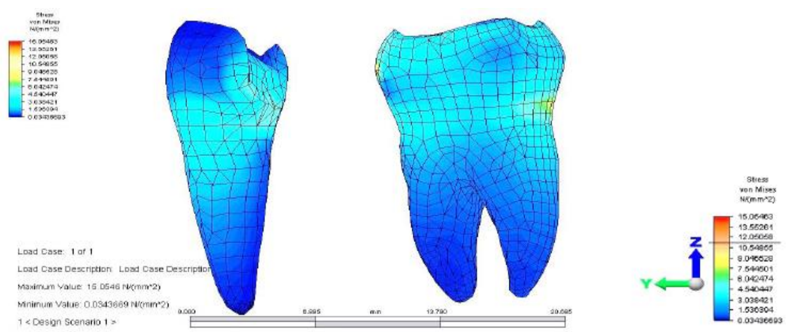


Fig.88 Tension distribution at abutments level when the force is placed in the 3.6 area

Regarding analyzing tensions in the mandible-abutments-dental bridge complex, when the reaction force acts on premolar 3.4, a tension jump is observed between the dental bridge and the teeth. This inequality is more evident at the junction between premolar 3.5 and the inlay applied on the occlusal surface of premolar 3.4. As a result of the reaction force exerted on tooth 3.4, the mandibular bone also supports a significantly higher tension (fig.89).

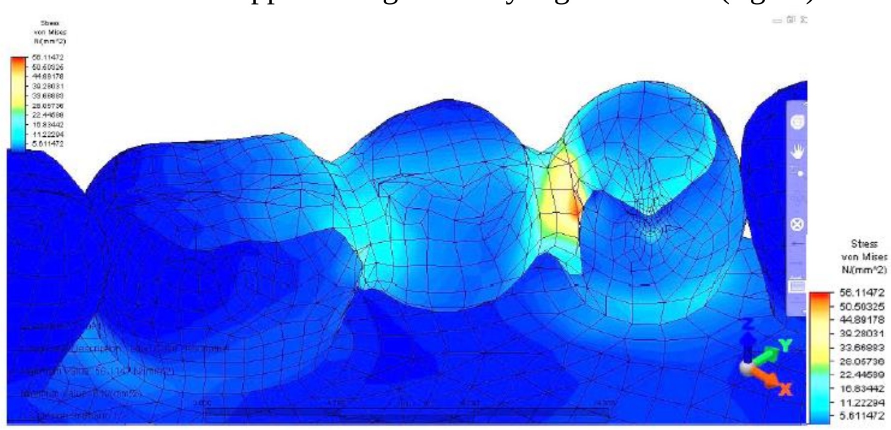


Fig. 89 Tension distribution at the bridge when the reaction force is placed in the 3.4 area

The pressure on abutments is also unevenly distributed. Stress distribution has a maximum value (12.553 MPa) on the premolar on which the reaction force acts. The dental bridge has an asymmetric stress distribution due to the reaction force, which has a maximum value of 56.114 MPa. However, the value is lower when the load is applied on the molar but higher when the force acts on the pontic. This is due to the greater distance of the premolar from the rotation center and also as a result of the direct action of the reaction force on premolar 3.4.

The pressure on abutments is also unevenly distributed. Stress distribution has a maximum value (12.553 MPa) on the premolar on which the reaction force acts. In addition, as in the case of applying for support on the molar, a higher value of tension is observed in the upper area of the root of premolar 3.4, towards the canine. Both in this situation and in the previous case, the direct action of the reaction force on abutments also determines a tilt of the supporting teeth (fig.90).

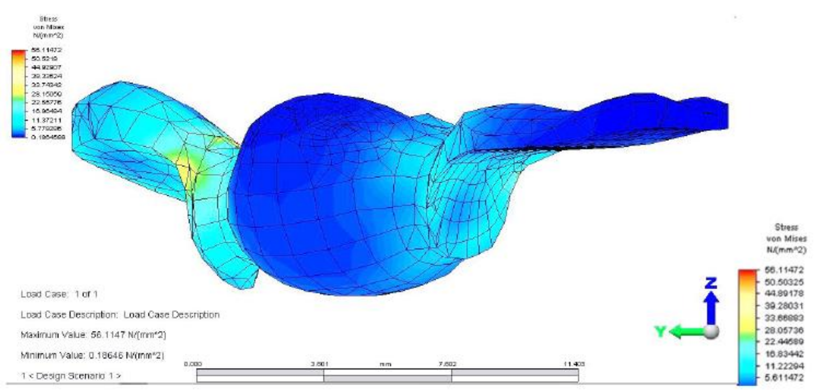


Figure 90 Tension distribution at the bridge level when the force is placed in the 3.4 area

If the load is applied to premolar 3.4, the mandibular bone has slightly higher tension values in the loading area. If the load is applied on molar 3.6, a jump in tension values is observed between the dental bridge and abutment tooth (fig.91).

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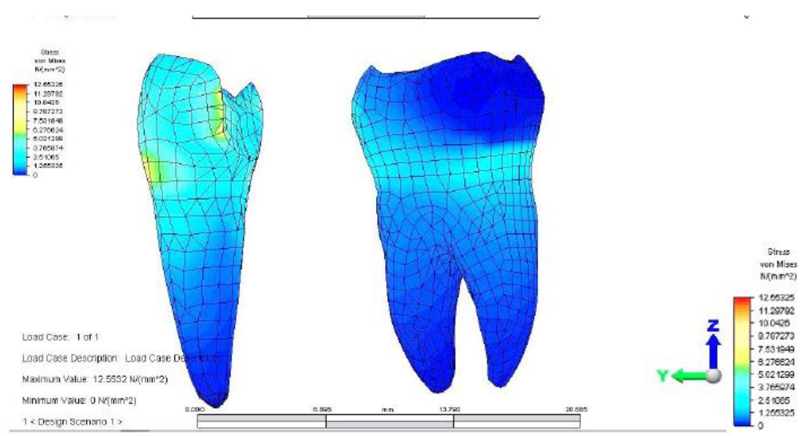


Fig.91 Tension distribution at abutments level when the force is placed in the 3.4 area

If we analyze the influence of food consistency on the abutment teeth the results obtained from a FEA on the restored system contain information about the stress distribution of each

element of the restoration, instead of only a single value of failure load typical of in vitro results. A correct interpretation of FEA results should be based on the stresses and strength of each component of the system.
For the analyzed items (dental abutments, dental bridge) a similar stress distribution is observed. The values for von Misses stresses were 54,33MPa into the bridge and 15.798 MPa in the supporting teeth (fig.92, fig. 93)

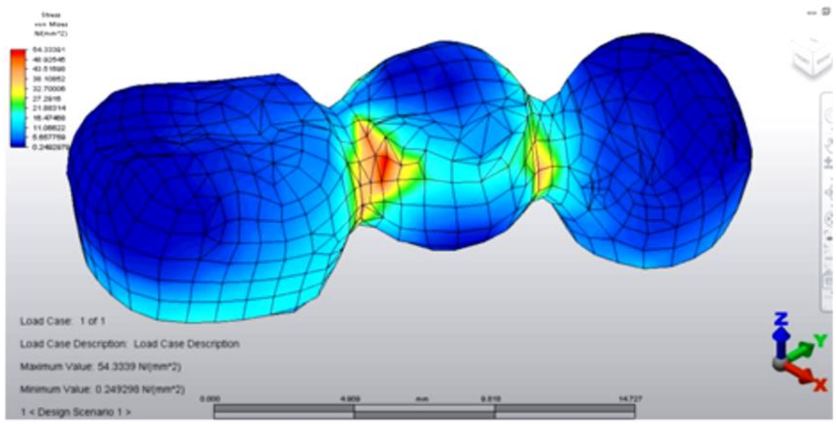


Fig.92 The von Misses Stress distribution and values registered on the bridge

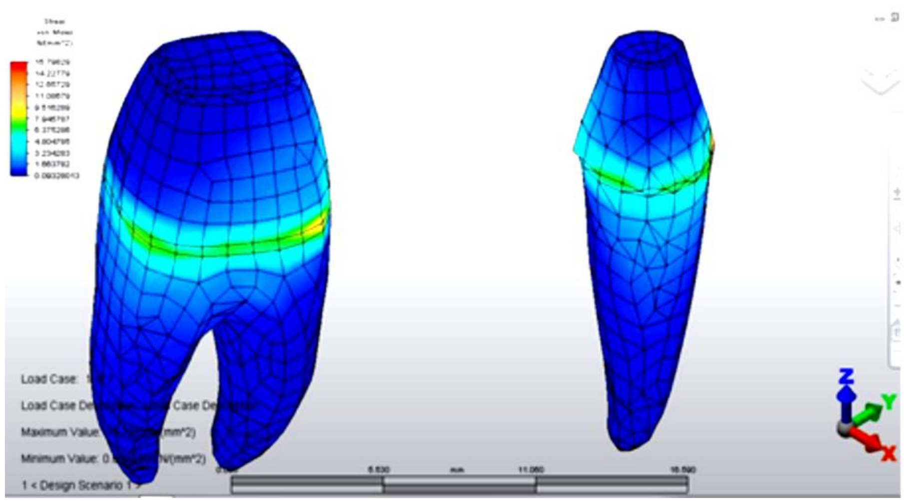


Fig.93 The von Misses Stress distribution and values registered on the abutments

Upon to the analysis of the forces acting on the bridge, we noticed certain stress concentrators, especially between the pontic and the abutment 34 when the food fragment was located on the occlusal surface of the mesial abutment, and on the distal surface of the abutment 36 when the food fragment was placed on the occlusal surface of the distal abutment, indicating the highest stress area, therefore the highest breaking risk.

Evolution of the highest tensions into the abutments for variable modulus elasticity of the food is presented in fig.94. No significant stress was registered until 200MPa modulus of elasticity, when the fist stress value recorded was 8,5Mpa.The maximum von Misses stress value on abutments was 18MPa, for a modulus of elasticity of the food fragment of 60000 MPa.

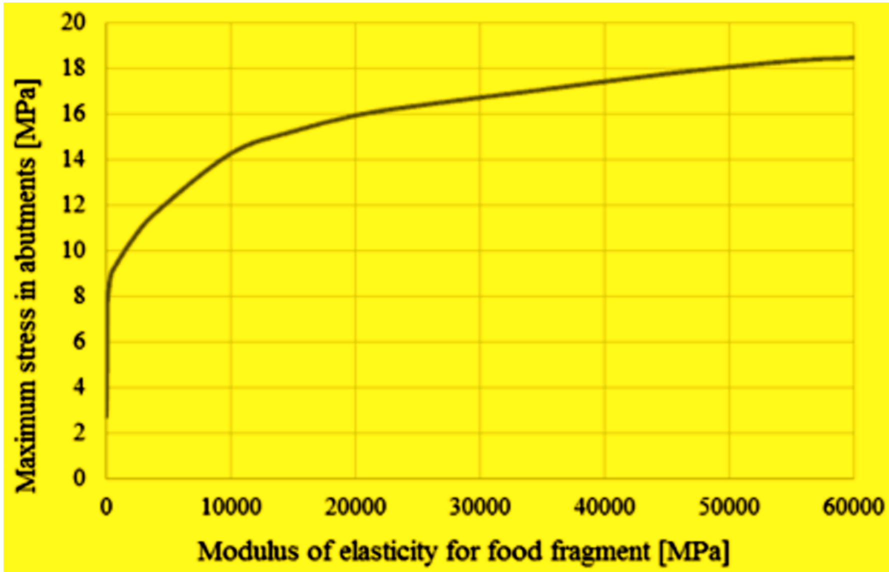


Fig. 94 The von Misses stress / food elasticity modulus diagram

Discussions

The mechanical characteristics of the materials that are used for prosthetic constructions are influenced by the technological steps. The conventional method that is described in our study, which uses heat-curing resins, involves a large number of laboratory steps, which leads to a longer working time, a longer number of treatment sessions, but also an increased risk of technological errors. On the other hand, this method allows for greater control over the morphology and marginal adaptation of the temporary bridges. Previous clinical studies have yielded conflicting results regarding the effects of fixed interim restorations on periodontal tissues (Skorulska et al., 2021, Lambert et al., 2017). However, the conventional wisdom is that fixed interim restorations featuring adequate marginal adaptation and proper finishing and polishing do not induce gingival inflammation, and this was supported by the present results (Al Jabbari et al., 2013)

Digital technologies substantially reduce the workflow, which is a great advantage for both the dental team and the patient. Several studies show that polymers that are used in digital technologies exhibit optimal mechanical parameters compared to conventional PMMA interim resin material. Therefore, these resins are indicated for long-term temporary bridges. The resins for digital technologies are fabricated under controlled industrial conditions and present improved mechanical properties, reduced residual monomers, and, due to the milling fabrication, they show no heat of reaction (Regish et al., 2011).

The results of this study reveal that there are no significant differences between the mechanical characteristics of heat-curing resin samples and those that are obtained by subtractive and additive digital methods.

Other authors reported small differences in fracture force, wear, and roughness between conventional and digital materials for temporary bridges. In vivo and in vitro aging led to comparable results in SEM evaluation. No significant differences in fracture force and wear but differences in roughness, heat of reaction, and thermal weight loss were found in extensive analyses, including simulation of aging processes and mechanical stability. Of course, the strength of temporary bridges is an important quality but not essential for these prosthetic constructions. In contrast, surface characteristics have a much greater impact on the longevity of these prostheses.

Surface roughness enhances plaque retention, promoting bacterial colonization, especially at the restorative margins, resulting in periodontal inflammation and infection. These drastic changes contribute to pulpal sensitivity, gingival recession, tissue inflammation, and complicate the challenge of restorative rehabilitation (Abdullah et al., 2018, Abdulmohsen et al., 2016, Hahnel et al 2019). Thus, to all these side effects which would compromise the final therapeutic solution and preserve the periodontal restorative interface, an optimal quality of the interim restoration is desired.

The surface roughness of a restoration alters under the influence of multiple factors, which include the fabrication technique, oral conditions, opposite dentition load, diet, material composition, and polishing techniques (Digholkar S. et al., 2016; Hahnel S et al., 2018; Alp G et al., 2018). In the present study, the surface roughness was assessed according to the fabrication technique: CAD/CAM subtractive method, 3D-printing, and the conventional technique. The highest surface roughness was observed in 3D-printing, with a similar outcome to the CAD/CAM milling technique. Nevertheless, the lowest roughness value was observed using the conventional samples. This indicates that conventional heat-cured materials can be successfully used in long-term temporary restoration.

Roughness, especially in the subgingival area, is considered the major cause of plaque buildup and the subsequent inflammatory response. Several sources of roughness have been described: strips and scratches on the surface of carefully polished acrylic resin, separation of the cervical crown margin, and the cervical margin of the finishing line by the luting material exposing the rough surface of the prepared tooth, dissolution and disintegration of the luting material causing crater formation between the preparation and the restoration, and inadequate marginal fit of the restoration.

The undersurface of pontics in fixed bridges should barely touch the mucosa and plaque formation determines gingival inflammation and even pseudo pocket formation. The preservation of periodontal health around the crown's margins is a serious challenge for a dentist and detecting the restoration margin relative to the neighboring bone is a significant factor when providing for the long-lasting health of the gingival tissues (Riccitiello et al., 2018). The final finishing of the prosthetic restoration affects the development of the microbial biofilm, as increased surface roughness creates a favorable environment for bacterial growth. As such, a prosthetic surface finish from proper manufacturing technique is important.

Most comparative studies have been performed on self-curing resins and resins that are used in digital technologies. Indeed, these resins that are used in the conventional technology, may undergo polymerization contractions, and may have a rougher surface. However, heat-cured resins that were used in our study, allow strict control over each stage, so these drawbacks can be removed.

Our results confirm that there is a statistically significant difference in terms of surface condition between the baseline values and the values after polishing ($p < 0.001$). The statistically significant difference was confirmed for each of the three resins, with similar p-values.

This is in line with the results that were suggested by the descriptive statistics, which revealed a sizeable downward trend. The same result holds true for all the three resins that were investigated in our study. For the heat cured sample, the difference is only statistically significant when looking at the Ra coefficients, but not for the other two measurements.

The sharpest reduction is displayed by the milled resin which displayed average reductions of more than 44% for each of the three measurements that were investigated. It is also interesting to add that the highest coefficients values are shown, on average, in the 3Dprinted samples. The means for this material was also confirmed to be statistically different from the means that were displayed by the other two resins that were used. The same result hold true after the polishing process. At the other end lies the heat-cured samples which reports the lowest averages.

It was shown that CAD/CAM temporary restorations have superior mechanical properties and superior surface quality compared with their conventional counterparts (Montero et al., 2021, Aldahian et al., 2021, Sadighpour et al., 2021, Rosentritt et al., 2020) as evidenced by our study.

The temporary prosthesis should not be considered as a useless stage with uncertain indications but as a way of transition from disability to functionality. The materials and methods which are used to make interim bridges are of a major importance for achieving this type of prosthesis.

The direct technique in the dental office is an alternative which is used in practice for temporary bridge fabrication. In this technique, the patient undergoes interim prosthesis in the same stage as the abutment preparation, which is an advantage because intermediate laboratory procedures are eliminated. However, the direct technique has significant disadvantages such as poorer marginal fit, pulpal damage due to the temperature released by the resin polymerization reaction, lower mechanical strength, and inaccurate dental morphological rehabilitation. Therefore, the routine use of directly formed interim restoration is not recommended when indirect techniques (conventional or digital) are feasible.

The research regarding finite element analysis, despite the limitations, provides valuable information and insight into the area of biomechanical research and offers clinical studies a base for development (Kareem et al., 2013, Al-Quran et al., 2011). In our study we chose to analyze an inlay retained dental bridge because this type of prosthetic construction has been less studied from a mechanical point of view in the literature. Furthermore, clinicians are reluctant to use this type of restoration because of a higher clinical failure percentage as a result of being a more technique-sensitive prosthetic solution. On the other hand, it is an important addition to the therapeutic options employed in clinical practice due to the fact that it can be used as a provisional prosthetic rehabilitation method during the 4-months period for bone healing and osseointegration of a dental implant (Cao et al., 2021).

In our study, when first developing the analysis, we evaluated the distribution of von Mises tensions at the pontic level, when the reaction force, opposing the muscular force, is located in the missing premolar 3.5 area. This phenomenon occurs due to the difference between the higher modulus of elasticity of the bridge alloy and the modulus of elasticity of abutment teeth. According to Hooke's law, at the same specific deformation, located at the tooth-restoration interface and at different modulus of elasticity, higher stresses result in the prosthetic restoration. We noticed higher tensions developing at the bridge elements junction, the highest value being between teeth 3.6 and 3.5. This high value of stress is explained by the smaller surface of the junction area, which in turn could constitute a potential fracture point. This result is in concordance with other studies in the literature (Tribst et al., 2019). Moreover, when evaluating the mandible-abutments-dental bridge as a whole, with the application of a reaction force on premolar 3.4, a tension jump is observed between the teeth and the dental bridge. This disparity is more obvious at the premolar 3.5 and the inlay applied on the occlusal surface of the junction with 3.4. The force is further transmitted to the mandibular bone due to increased stress, which upholds a considerably higher tension.

Results similar to ours were obtained in a study that analyzed three interim restorative materials by the FEM method regarding stress resistance. The authors found that the biggest tensile stress magnitude, regardless of the restorative material, was in the region of the prosthetic connector, and the highest stress peak was observed in resin composite, followed by poly-ether-ether-ketone and acrylic resin (Campaner et al., 2021).

The asymmetric stress distribution of the dental bridge is due to the placement of the reaction force. Thus when the load is applied to the molar, the value is lower. However, it is higher when the force is placed directly on the pontic. This situation can be explained because the premolar is further from the rotation center and the reaction force, which acts directly on tooth 3.4. Moreover, the abutments have an uneven stress distribution, the value being elevated on the premolar on which the reaction force acts, and an augmented value of tension is noticed in 3.4, towards the coronal area of the root, near the canine. In both analyzed scenarios, there is a tilt of the supporting teeth caused by the direct action of the reaction force on abutments.

A study by Bromicke evaluated the load-bearing capacity, load at initial damage and the failure pattern of posterior resin-bonded fixed dental prostheses to replace a maxillary first molar fabricated from veneered cobalt–chromium, veneered zirconia and monolithic zirconia. Of all tested models, veneered resin-bonded fixed prostheses were more prone to cracking of the veneer component (Bömicke et al., 2020). Other authors observed similar results, who compared fracture resistance of veneered zirconia and metal–ceramic inlay-retained fixed dental prostheses and pinpointed the veneer as being the weakest component (Bakitian et al., 2020).
Another study, which used the finite element method aimed at testing materials to restore a missing mandibular first molar, found no difference between a posterior inlay retained full zirconia fixed dental prosthesis and a chromium cobalt substructure, porcelain coating, and adhesive resin as wings. The authors applied a load of 400 N and observed a slight advantage regarding stress-bearing for zirconia, however, not significantly when compared to the chromium cobalt substructure and porcelain coating (Bömicke et al., 2020, Yossef et al., 2018)

Other factors that could further influence fracture resistance are the design of the preparation, framework design, and surface treatments of fixed dental prosthesis (Malysa et al., 2021, Ciocan-Pendefunda et al., 2018)

According to some researchers the highest fracture resistance values were observed in the case of the butterfly wings design followed by inlay and box designs. Furthermore, the additional surface treatment by sandblasting and tribochemical silica coating of zirconia surfaces displayed the highest mean fracture resistance values when compared to Er, Cr: YSGG laser (Samhan et al., 2020, Alpízar et al., 2020)

Bone density and width of maxillary bones in the edentate area have an important impact on the choice of the future prosthetic appliance, which can be applied. Thus instruments, which analyze these parameters are of utmost relevance, especially when considering implant placement. Furthermore, a mechanical risk evaluation before placing inlay-retained dental bridges or before placing other therapeutic options, especially implant treatment using endoral radiographs, orto-panoramics and cone-beam computer tomography and other paraclinical examinations, should be an obligatory step in treatment planning (Cosola et al ., 2021).

The most fragile part of the bridge is represented by the junction between the pontic and the retainers; the smaller the section of this area, the more prone it will be to fracture. Our study confirmed these results; furthermore, we also emphasized the distribution of forces on the bridge elements and on abutments, highlighting the areas of maximum load, as clinical maneuvers, such as periodontal instrumentation, can further weaken the resistance of abutment teeth (Lakshmi et al., 2015, Kale et al., 2020).

Knowing the vulnerable areas, clinicians will have useful information for designing such a dental bridge and will have the opportunity to increase stability and retention. The results of our study show that the inlay-retained dental bridge represents an optimal therapeutic solution, in terms of the resistance of abutments, with the added benefit of an important economy of dental tissues.

Conclusions

The clinical longevity of prosthetic appliances depends on the biomechanical properties of the used materials. In vitro tests represent essential research methods, because the application of forces is comparable to the physiological way in which this phenomenon occurs in the oral cavity, reproducing the pattern of strain among physiological and parafunctional functions, and thus partly eliminating the need of difficult and time-consuming clinical experiments. The dental staff has to be permanently connected to the last offers regarding dental materials and their most modern testing methods, in order to choose the optimal solution in every clinical case.

The finite element analysis is an extremely useful method of following the behavior of prosthetic constructions and supporting teeth, subjected to the pressures exerted by masticatory forces. This technique demonstrated that stress determined by the loading force is not able to cause damage to the prosthetic device or to abutment teeth. However, special attention must be paid to its design, especially in the connection area between the bridge elements, because connectors and retainers represent the weakest parts.

The inlay-retained dental bridge for single tooth replacement is a viable alternative, not only from a clinical point of view as the integrity of dental tissues are preserved to a very large extent but also from a biomechanical point of view. Thus, it can be considered an optimal economical solution for treating class III Kennedy edentation in young patients or as a provisional pre-implant rehabilitation option. From a stress standpoint, the distribution on the abutments has the maximum values on the cervical area and on the bridge the stress is increasing distal between the retainer and the pontic related to the modulus of elasticity of the food fragments. The clinical longevity of the supporting teeth depends therefore also on the alimentary behavior of the patient. The Finite Element Analysis method has advantages over methods that use real patterns. Analyzes are repeatable, there are no ethical considerations, and working hypotheses can be changed or modified sequentially.

Temporary prosthetic constructions are of major importance in the therapeutic strategy and have the role of preventing functional imbalances and the occurrence of local and loco-regional complications. To achieve interim prosthesis it can be used different methods and materials, depending on the purpose and the period of applicability of these types of prosthetic constructions.

Following the studies we carried out regarding the materials and technologies for temporary bridges, we can conclude that the subtractive method can allow obtaining resistant devices with low roughness structure. At the same time, we can ensure an optimal restoration of the teeth morphology and a correct functional rehabilitation. Therefore, these methods can be used to make long-term interim prosthodontics restorations.

In this stage of the research, we focused on the analysis of some frequently used resins in the dental laboratory for temporary bridges realization. In order to obtain even more relevant results, the study will be continued, taking into account other resins that are used for these prosthetic constructions.

In the current era, conventional methods using heat-curing resins are still a viable alternative and these materials can be successfully used for short-term temporary prosthetic restorations.

Digital technologies have a lot of advantages, but it still cannot and should not replace traditional know-how and therefore cannot replace skills and technical expertise. In digital methods, the data collected will always be available and it can be used to produce the provisional restoration and the final restoration; this avoids repeating the same steps twice.

An intelligent collaboration of conventional and digital procedures is possible and can lead to excellent results even more safely and more efficiently. These new technologies should be seen as opportunities, help and support rather than something to be feared of.

3. IMPACT OF THE MATERIALS USED FOR REMOVABLE PROSTHETIC CONSTRUCTIONS ON ORAL STATUS

Introduction

Complete and partial edentulism are the most severe and irreversible form of edentation, which leads to imbalances in all elements of the stomatognathic system. That is why practitioners and researchers have been continuously concerned over time in order to find an optimal therapeutic solution, which would allow the restoration of all the affected functions.

Acrylic dental resins, especially poly-methyl-methacrylate (PMMA) resin, are commonly used in dentistry as denture base materials, due to their advantages, such as relatively high strength, acceptable hardness, color stability, insolubility in the oral cavity, low weight, low conductivity (Martori.et al., 2014, Al-Fouzan et al., 2017). However, these materials have numerous drawbacks frequently reported by practitioners, the most common of which are poor mechanical strength, susceptibility to staining curing shrinkage, and water sorption (Diaconu-Popa et al., 2021, Srinivasan et al., 2021).

The water sorption can determine dimensional changes of the denture, and the increase in dimension of the denture during immersion in water or saliva does not always compensate for the curing shrinkage (Vitalariu et al., 2019).

In the last decade, digital technologies have become an alternative to conventional fabrication of acrylic removable dentures (Prpić et al., 2020). These methods substantially reduce workflow, facilitate quick communication between the dentist and the dental technician, and increase patient comfort (Diaconu-Popa et al., 2021).

Most available systems use subtractive and additive manufacturing to fabricate acrylic-based dentures (Srinivasan et al., 2018, Abualsaud.et al., 2022). The materials used in these technologies are industrially produced, so they have superior chemical and volumetric stability and optimal mechanical strength (Perea-Lowery et al., 2019, Al-Dwairi et al., 2019, de Oliveira Limírio et al., 2022, Steinmassl et al., 2018). Subtractive systems use pre-polymerized acrylic discs, from which, based on the information received from the CAD unit, the future prosthesis will be milled. Milling strategies allow for obtaining a well-fitted prosthesis with high-accuracy surfaces (Hsu et al., 2020, Masri et al., 2020, Kalberer et al., 2019, Srinivasan et al., 2021). Several 3D printing technologies have been employed in dentistry, including stereolithography (SLA), digital light processing (DLP), selective laser sintering (SLS), selective laser melting (SLM), electron-beam processing (EBM), polyJet photopolymer printing, and fused deposition modeling (FDM). However, stereolithographic printing of light-cured polymers has gained popularity (Baciu et al., 2022).

Additive methods reduce the workflow, the numbers of appointments, allows reproduction of all details, and reduced waste of material (AlHelal et al., 2017, Javaid et al., 2019).

Printing parameters, such as laser intensity, calibration of printer and software, resin properties, build direction and angle, layer thickness and numbers, the bond between the layers, amount of supporting structures, and post-polymerization conditions, play an important role regarding the quality of the final product (Katheng et al., 2021). It is a huge responsibility for dental staff to fabricate high-quality removable dentures, and it is important to know the details and particularities of each method.

Digitalization in the prosthetics field has already activated research and clinical potential and will do significantly more in the near future; consequently, these systems must be studied to determine their advantages and downsides.

A removable denture requires a considerable number of clinical and technological procedures, as well as digital approaches that have the benefit of drastically lowering the amount of work required. On the other hand, the expenses of such a technical line are still rather high, and many experts do not view the procurement of equipment for producing detachable prostheses via additive or subtractive methods as a lucrative investment.

Finite element analysis (FEA) is a computational method that allows for the accurate modeling and analysis of complex structures, making it a valuable tool in a wide range of fields, from engineering to biology. Since Finite Element Analysis (FEA) is a numerical method capable of evaluating stresses and deformations in structures, it has become a widely accepted and non-invasive approach for studying the biomechanics of biological systems and understanding the impact of mechanical forces on them (Tatarciuc et al., 2018).

Over the last few years, there has been rapid progress in the field of materials used for fabricating removable dentures. Nonetheless, the most recent studies on the mechanical and surface properties of resins do not cover the entire range of commercially available products across all countries.

Our study is highly valuable for current practice as it analyzes the most used acrylic resins in our laboratories, replicating the real technological working flow involved in prostheses fabrication. The current research aims to perform a comparative analysis of the selected mechanical characteristics of three types of resins used in conventional, subtractive, and additive technologies and to determine the optimal material and the most appropriate technology to obtain removable dentures with the highest mechanical longevity over time. Additionally, for ensuring the precision of the outcomes, we evaluate the FEA software's ability to predict the direction of crack propagation, as well as provide valuable insights related to stress and strain phenomena.

The null hypothesis was that the mechanical and surface properties of the samples are unaffected by the fabrication process.

The impact of materials used for removable prosthetic constructions on oral status are illustrated by the following publications:

1. Baciu E-R., Savin C.N., Tatarciuc M., Mârțu I., Butnaru O.M., Aungurencei A.E., , Mihalache M.A., **Diaconu-Popa D.** An Experimental Study Regarding Mechanical Properties of Different Resins Use in Oral Environment, *Medicina*, 2023

2. Diaconu-Popa D., Vițalariu A., Mârțu I., Luchian I., Luca O., Tatarciuc M. Full dentures realization -conventional vs digital technologies, *Romanian Journal of Oral Rehabilitation*, 13 (4) , 2021, 160-173

3. Viţalariu A, Tatarciuc M, Cotaie GH, **Diaconu D.** In vitro testing – an esential method for evaluating the performance of dental materials and devices, *International journal of medical dentistry,* volume 5, issue 2, april / june 2015 http://www.ijmd.ro/index.php?link=articole&anul=2015&nr=2&vol=19#a1

4. Tatarciuc M., Luchian I., Vițalariu A., Mârţu I., **Diaconu-Popa D.** Study regarding the technologies for completedentures realization, *Romanian Journal of Oral Rehabilitation*, Vol. 13, No. 3, 2021, pp. 200-211

Materials and Methods

Study design

In order to investigate the properties of denture base materials, 90 samples (Fig. 95) were manufactured using resins used for conventional and CAD-CAM subtractive and additive-fabricated dentures. For the experimental tests that were conducted, the resin samples were divided up into the three main groups, as shown in Table XXV.

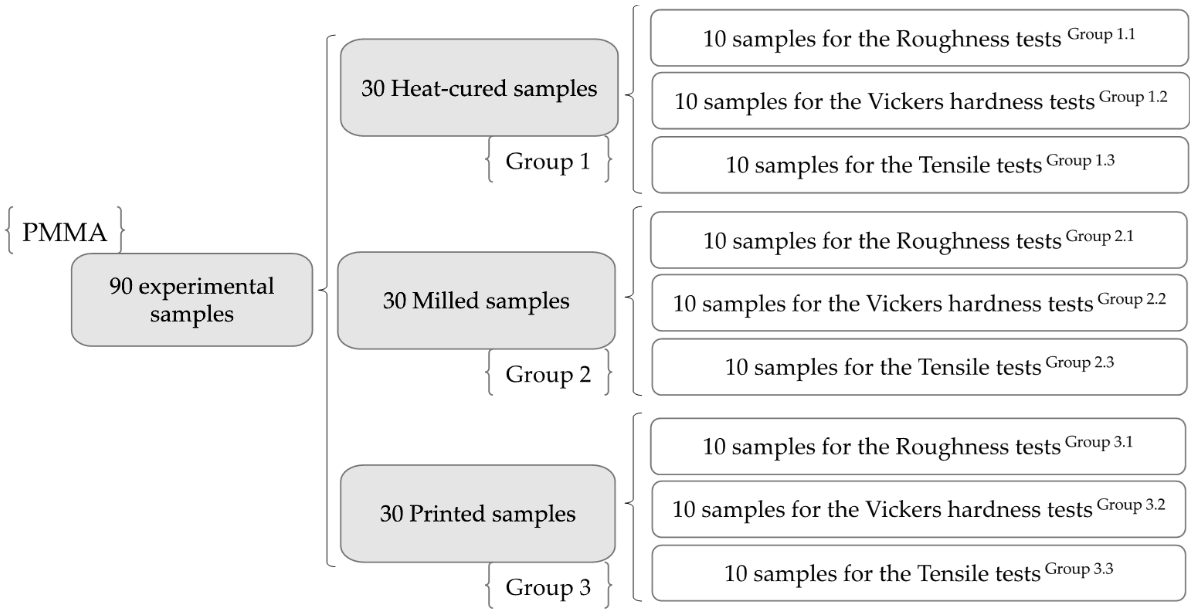


Fig.95 The experimental sample framework.

Table XXV. Resin groups with their product information and experimental equipment.

Resin Groups	Resin	Experimental equipment		
		Surface roughness	**Vickers hardness**	**Tensile tests**
Group 1 Heat-cured group	Meliodent Heat Cure (Kulzer GmbH, Hanau, Germany)	Form Talysurf® tester (Taylor Hobson, Leicester, England)	HVT-1000 (Shanghai Daheng Optics and Fine Mechanics Co., Ltd., Shanghai, China)	Instron 2716-002, Instron, Norwood, United States
Group 2 Subtractively manufactured group	Polident (Polident d.o.o, Volja Draga, Slovenia)			
Group 3 Additively manufactured group	Asiga DentaBASE resin (Asiga, Alexandria, NSW, Australia)			

The samples design

For the hardness and roughness tests, rectangular samples with 30 mm width, 70 mm length and 2 mm thickness were made (Fig. 96 a).

Dumbbell-shaped samples were used for tensile testing, with dimensions chosen according to ISO 527-2 and ASTM D-638 standards (Fig. 96 b).

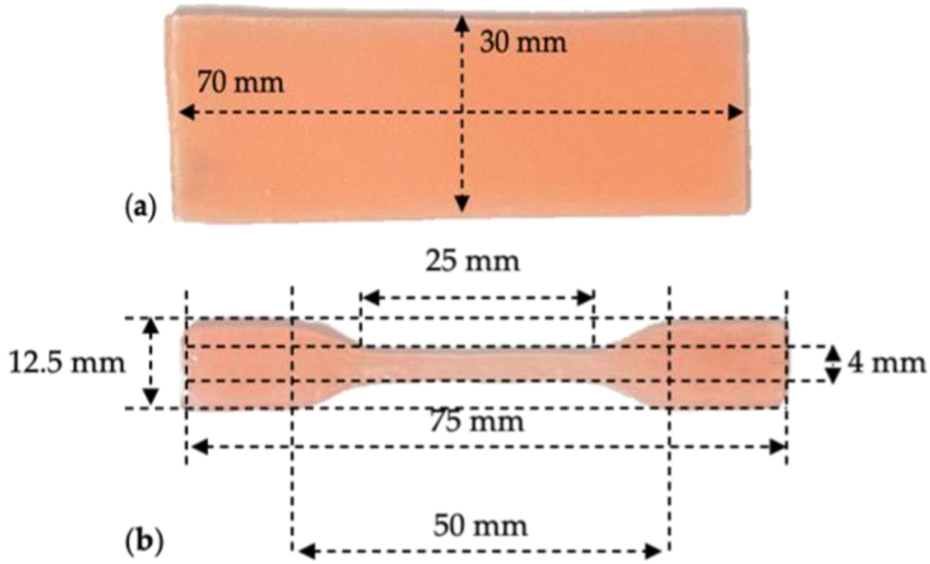


Fig 96 The samples design: (a) For the hardness and roughness tests; (b) For the tensile test

PMMA samples realization

1. Heat-cured samples

For the heat-cured samples, wax patterns were invested in a Type 3 dental stones (Moldano, Kulzer GmbH, Hanau, Germany) respecting manufacturer processing instructions: mixing ration 100g powder:30ml water, under vaccum for 30 secounds.

Then the metallic flask was immersed in 100 °C water for five minutes; the two sides of the flask were separated; the wax fragments were cleaned, and the mold was isolated using alginate solution Isodent (SpofaDental Inc., Jičín, Czech Republic). The recommended mixing ratio for the resin preparation is 35 g powder to 14 ml liquid; the liquid was added to the mixing beaker along with an appropriate amount of powder, which was then stirred for one minute using a spatula. After 10 minutes, Meliodent Heat Cure (Kulzer GmbH, Hanau, Germany) reaches a packable consistency and can be manually pressed into the mold. The flask was immersed in boiling water for 15 minutes, after which the heat source was switched off. According to the manufacturer's recommendations, a short cycle method was used in the polymerization process. The flask was allowed to cool slowly in a water bath after 20 minutes of boiling. Following polymerization, specimens were extracted from the mold.

2. Milled samples

The wax patterns were scanned with a Swing DOF Scanner (DOF Inc., Seoul, South Korea) and the computer-aided machine automatically milled (VHF K5 Plus, VHF, Ammerbuch, Germany) the experimental samples from CAD/CAM pink denture bases resindiscs (Polident, Polident d.o.o, Volja Draga, Slovenia) measuring 95 mm in diameter and 25 mm in thickness.

3. Printed samples

STL files were submitted to the digital light processing (DLP) printer (Asiga MAX, Asiga, Alexandria, NSW, Australia) for fabrication using Asiga DentaBASE resin (Asiga,

Alexandria, NSW, Australia). After the printed samples were removed from the build platform, they were cleaned with 99% isopropyl alcohol and dried with steam.
Finally, a 20-minute post-polymerization process was required, which was conducted using the Asiga Flash Post Curing Unit (Asiga, Alexandria, NSW, Australia).

4. Finishing and polishing

During the sample processing phase, we utilized the Acrylic Contouring & Finishing Kit HP (Shofu Dental GmbH, Ratingen, Germany) for denture finishing and polishing. Initially, a dark gray AcryPoint coarse-grit BP1 tool (Shofu Dental GmbH, Ratingen, Germania) was utilized for 60 seconds (in dry conditions), and then, a brown AcryPoint medium-grit BP1 (Shofu Dental GmbH, Ratingen, Germania) was used respecting the same duration. The instruments' rotational speed was rather modest, at 10,000 rpm.

A light gray AcryPoints tool (Shofu Dental GmbH, Ratingen, Germany) and a gentle circular goat hair brush were employed at an even slower speed of 4,000 rpm (60 seconds in dry conditions) for fine finishing.

For polishing, a Pala Polish Polishing paste (Kulzer GmbH, Hanau, Germany) was applied first to the samples, and then the procedure was carried out with a rag wheel (Kulzer GmbH, Hanau, Germany), 3 times for 60 seconds, to achieve a flawless sheen.

Experimental tests

1. Roughness tests

For each sample, six measurements (three records before and three, after finishing and polishing) were taken at the level of the examined surface using contact-type roughness tester Form Talysurf® (Taylor Hobson, Leicester, England).

Based on the determined roughness parameter values the influence of finishing on the micrometric profile of each surface (ΔR_a) was calculated:

$$\Delta R_a = R_{a\ \text{before finishing}} - R_{a\ \text{after finishing}}$$

R_a- the arithmetic mean roughness

2. Vickers hardness tests

The Vickers tests were performed on HVT-1000 automatic measuring Vickers hardness tester (Shanghai Daheng Optics and Fine Mechanics Co., Ltd., Shanghai, China), using 50 gf load force, for 10 seconds. On each sample, five determinations were made.
The Vickers hardness (HV) was calculated using the following formula:

$HV=1854.4L/d^2$, L - the load force in gf; d - the average diagonal in µm.

3. Tensile tests

Standard tensile tests were conducted at room temperature in accordance with ISO 527-1: 2000 [25], and computer-controlled testing equipment was used for direct strain measurement (Instron 2716-002, Instron, Norwood, United States).
Young's modulus and tensile stress at Yield were determined using a 1 mm/min crosshead speed.
Young's modulus (E), was calculated according to the Hook's law:

$$E = \sigma/\varepsilon$$

σ – tensile stress (the amount of force applied per unit area, $\sigma = F/A$); ε – tensile strain (the extension per unit length, $\varepsilon = dl/l$).

4. Finite element method (FEM)

The finite element method (FEM) goal was to model a fracture similar to the ones obtained after tensile tests that would give us stress and strain distribution that otherwise are very difficult to measure. Our choice of software is Ansys (Ansys, Canonsburg, PA 15317, USA). First, we had to design the materials that would have similar mechanical properties of one that we have used in our research. None of the three resins are available as a library source that could be used inside simulation, therefore we have used Ansys's specific tool, Material Designer. Commonly, polymethyl methacrylate (PMMA) resins are most used for denture applications. We aimed at designing materials similar to those used for mechanical testins. For that purpose, we have accessed the software library that contains various types of materials, named Engineering Data. From the composite materials section we have added a Polyamide resin and Epoxy E-Glass (Safwat E.M et al., 2021). Those two are needed when designing the material similar to an PMMA. In order to create a material, the software first requires a matrix for which we have selected the resin and the binder in form of particles for which we have selected the epoxy. The next step consists of selecting a geometry for the inner arrangement at macromolecular level which we have set to a random particle distribution with default values of 15430 seed and 0.3 particle volume fraction with a 10 µm particle diameter. The diameter distribution was set to constant. The resulting particle arrangement can be observed in fig.97 with mentioned settings.

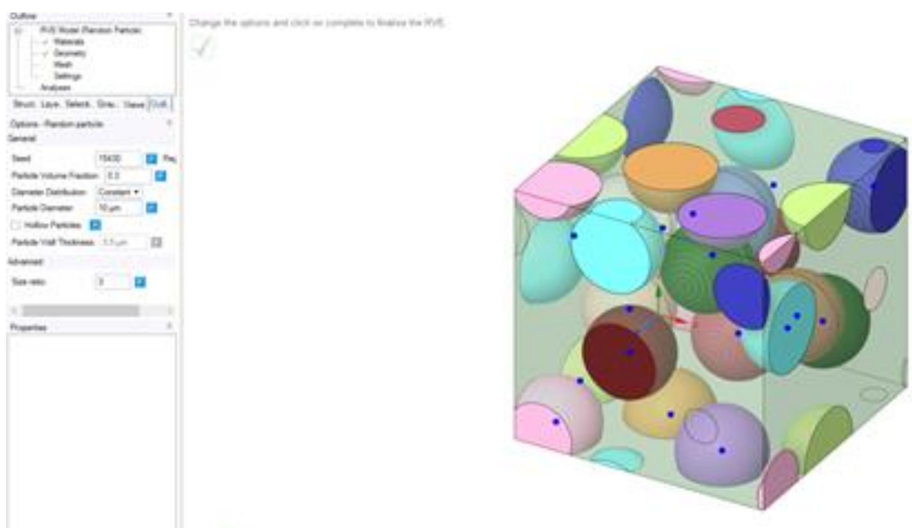


Fig.97 Material designer setup related graphical representations of the: 3D view of the random particle type of arrangement

Mesh wise we have chosen a conformal and periodic meshing without imposing a maximum size for its elements. Our choice for anisotropy is orthotropic and we have computed a linear elasticity property without the need for coefficients of thermal expansion or thermal conductivity. We have used periodic boundary conditions option for our analyses and have chosen a constant material type of solver which we have named generically PMMA. The software computes and gives us a Young's modulus of 3255.3 MPa on XY, 2725.4 MPa on YZ and 2718.2 MPa on XZ. For Poisson's ratio we have 0.38701 in XY, 0.39117 in YZ and 0.41716 in XZ. Density is reported to be of 1.4066E-09 t mm^-3 (Fig.98).

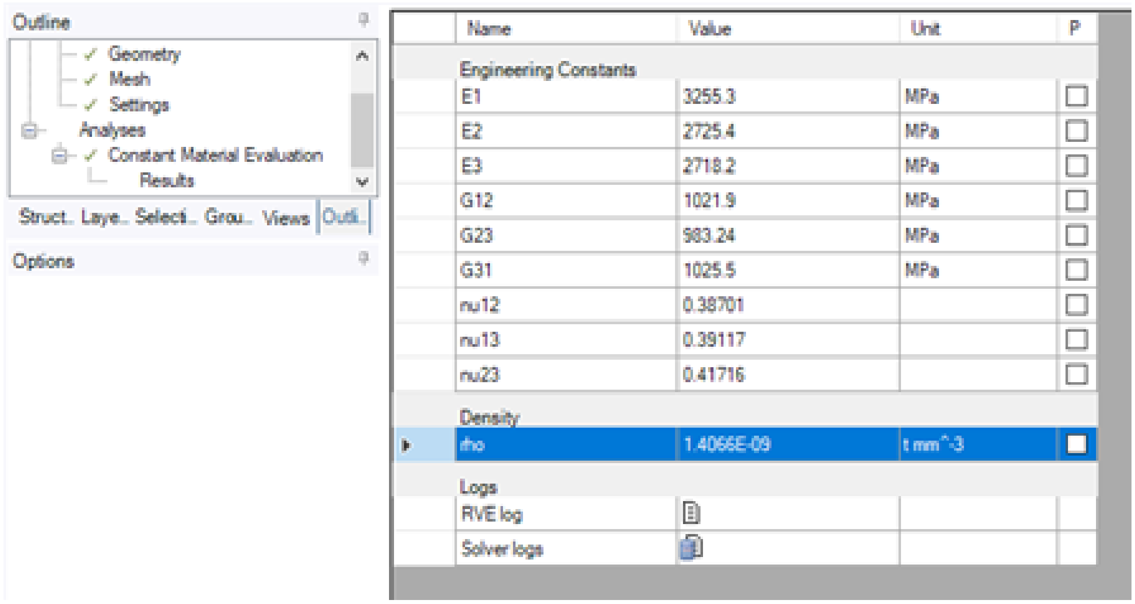


Fig.98 Material designer setup related graphical representations of the view of results that were obtained.

The newly designed material needed for finite element analyses was imported into the Engineering Data section of a Static Structural type of analysis. In order to obtain a fracture direction, we had to model in a 3D software solution (Siemens SolidEdge academic, Siemens, Munich, Germany), the sample with exact geometric dimensions as the ones specified by standards and used inside experimental tensile tests. Based on the results of the tensile tests we have designed a pre-crack about the same height as the area where the fracture appeared after tensile tests. The 3D model was later translated into a Parasolid file that is easy to be interpreted by the software.

By reading the internal library, namely Engineering Data, we were able to assign to the imported geometry the newly created material. Because of the process complexity we have used a virtual topology tool based on edge mapping type of behaviour. Our choice for predicting a crack direction is for SMART crack growth tool available in Ansys. This is suitable for our setup because crack growth simulation expands in homogenous environments in need for structural integrity which is the case for our specimen. The criterion is in fact a rate of energy release type of method which uses stress intensity factors (SIFs) for assessments. We chose a static crack type of growth which calculates the extension of each front node of the crack. We had to generate a new coordinate system specific to the crack itself where the X points to the direction of propagation and the Y sits almost normal to its upper face. Mesh wise we have imposed a patch conforming method that uses quadratic element order and a face meshing method for both of the crack's faces with just 0.25 mm element size as the mesh general settings was set to 0.5 mm with aggressive mechanical type of error limits assessment. That resulted in 9590 elements and 18210 nodes (Figure 3). Fracture tool includes a pre-meshed crack with six solution contours and the SMART crack growth tool set to static. The chosen option for failure

criteria is stress intensity factor with a 100 MPa·mmˆ(0.5) critical rate. Analysis settings received a 0.001 sec end time defined by ten sub-steps. Conditions were set in form of a fixed support on the lower face of the sample and a force solicitation on the upper face (Fig.99).
Equivalent elastic strain registers a little over 0.008 mm/mm (Fig. 99 a) as the propagation direction is similar to the one observed at our tested samples and the equivalent stress evaluated by means of Von-Mises criteria reaches 1634.8 MPa along the fracture line (Fig.9.b).The analysis stops just before the body gets separated.

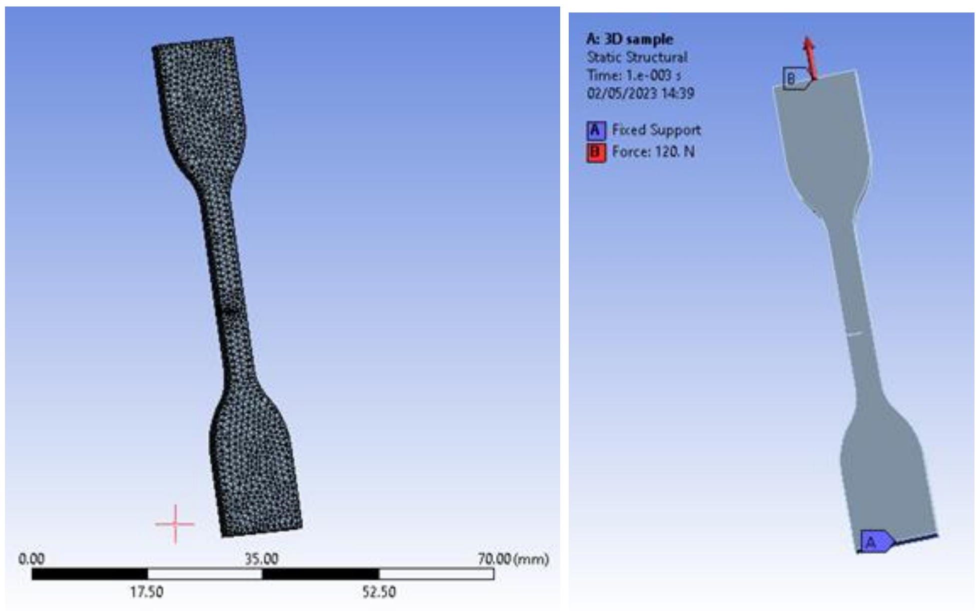


Fig.99 Setup related graphical representations of the: (**a**) 3D view of the meshed body; (**b**) 3D view with supports and conditions applied on the sample body.

5. The statistical analysis

For the statistical data analysis, Stata 16.1 software (StataCorp, Texas, United States) was used. The one-way ANOVA analysis was employed to check if there are statistical differences in terms of surface roughness, hardness and tensile parameters across the three types of resins used. Furthermore, the Bonferroni multiple-comparison test was used to check where the statistically significant difference lies by zooming in on each of the possible paired samples. The statistical analysis was carried out at a $p<0.05$ significance level.

Results

Evaluation of the roughness parameters

The findings from the statistical analysis for the compared roughness parameters are shown in Table XXVI.

The results of the roughness coefficients before finishing and polishing revealed a statistically significant difference between the three groups ($p<0.001$). However, the

Bonferroni multiple-comparison test indicated that it is only the 3D printed samples which are, on average, different compared to the other two groups (p<0.001).

Table XXVI The roughness parameters values for the studied samples.

Group	Number of samples	Mean values±Standard deviation		
		Ra before finishing and polishing [µm]	Ra after finishing and polishing [µm]	ΔRa [µm]
Heat cured	10	0.239± 0.024	0.037± 0.008	0.201±0.022
CAD-CAM milled	10	0.267±0.044	0.046±0.011	0.221±0.035
3D printed	10	0.494±0.028	0.050±0.007	0.445±0.027
F(df)		177.24(2,27)	5.33(2,27)	224.11(2,27)
p-value		0.000	0.0112	0.000

[1] The one-way ANOVA was used. The significance level was established at 5%.

The results of the roughness coefficients before finishing and polishing revealed a statistically significant difference between the three groups (p<0.001). However, the Bonferroni multiple-comparison test indicated that it is only the 3D printed samples which are, on average, different compared to the other two groups (p<0.001). As also displayed by Figure 100, on average, the heat cured sample display the lowest roughness coefficients.

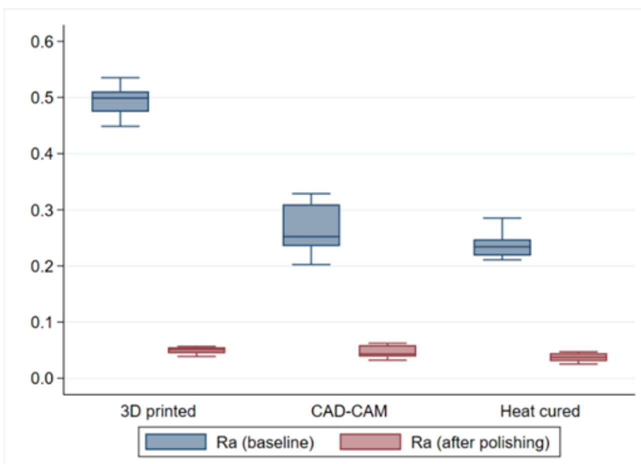


Fig.100 Box plot of surface roughness by resin, before/after polishing

After polishing and finishing, as expected, the average roughness coefficients dropped in all the three methods, with the heat cured sample still reporting, on average, the lowest coefficients. The ANOVA confirmed that there is still a statistically significant difference in roughness between the groups (p=0.0112). Nonetheless, the difference is only significant between the 3D printed and the heat-cured samples, as indicated by the Bonferroni test (p=0.011). Finally, when investigating the differences in terms of averages across the study's groups, the results confirmed a significant difference between them (p<0.001).

Evaluation of the Vickers hardness

At a magnification of 400:1, Figure 101 a-c illustrates the indentations produced by the indenter on the surface of the samples subjected to Vickers hardness analyses.

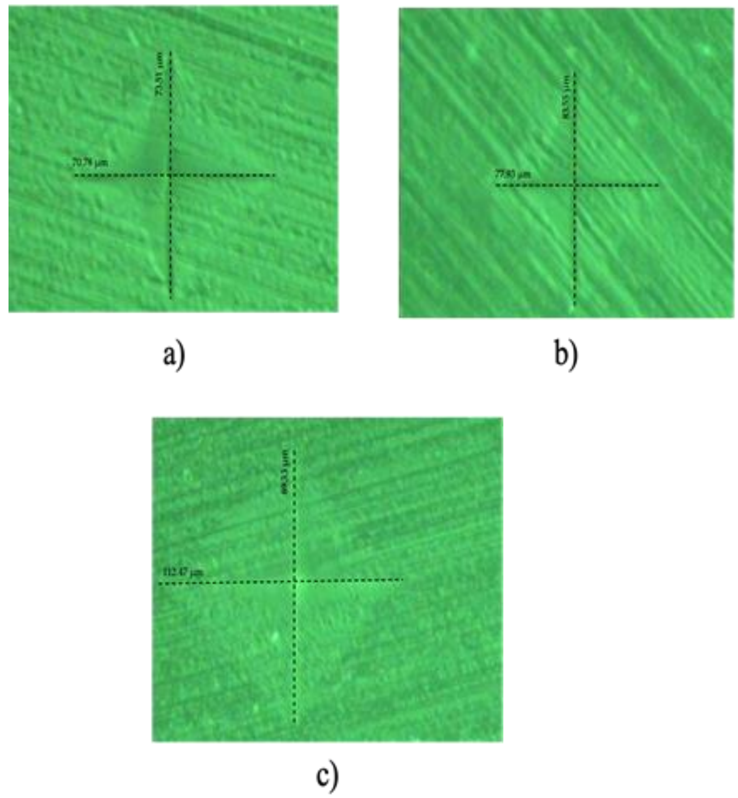


Fig.101 The impressions of the penetrator on the surface of the samples: (**a**) Group 1.2- Sample 3 heat-cured; (**b**) Group 2.2- Sample 2 CAD-CAM milled; (**c**) Group3.2- Sample 8 3D printed.

The average values of the determinations are presented in Table XXVII with the 3D printed sample reporting, on average, the smallest HV coefficients.

Table XXVII Vickers hardness values for the studied samples.

Group	Number of samples	Mean values±Standard deviation Vickers hardness HV
Heat cured	10	20.257±0.854
CAD-CAM milled	10	22.301±1.115
3D printed	10	13.853±0.586
F(df)		251.63(2,27)
p-value		0.000

The one-way ANOVA was used. The significance level was established at 5%.

When looking at the distribution of our samples, the CAD-CAM milled sample clearly displays, on average, the highest Vickers. At the other end lies the 3D printed sample, with the lowest values (Fig.102).

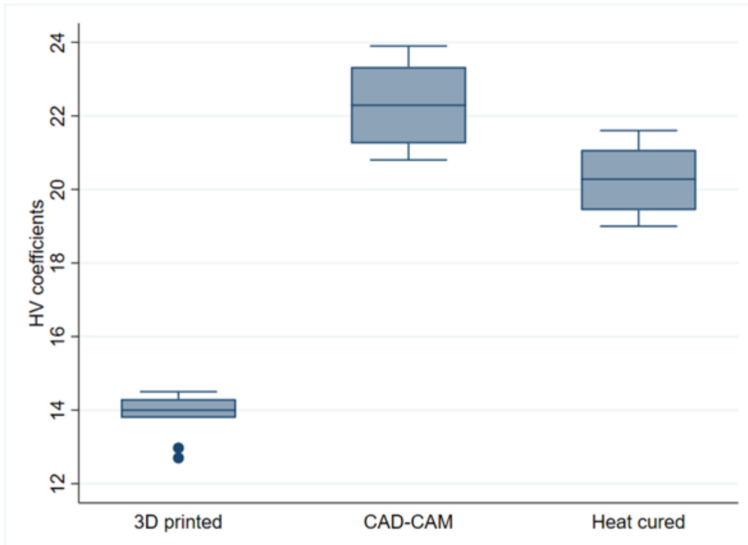


Fig.102 Box plot of Vickers hardness values by resin used.

The one-way ANOVA test revealed that the type of resin used is decisive for surface hardness [$F(2,27) = 251.63$, $p<0.001$]. According to the Bonferroni multiple-comparison test, there was a statistically significant difference in the mean values of the HV coefficients for all potentially matched samples ($p<0.001$).

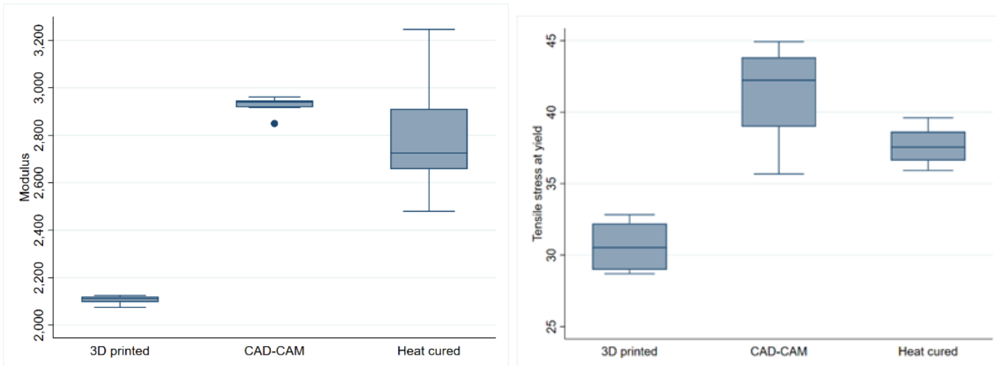
Evaluation of Tensile parameters

The average values of the modulus and tensile stress at yield obtained by the tensile test are shown in Table XXVIII.

Table XXVIII Average values of the mechanical characteristics obtained by tensile tests of the experimental samples.

Group	**Number of samples**	**Mean values±Standard deviation**	
		Modulus (Segment 0.0005 mm/mm - 0.0025 mm/mm) [MPa]	Tensile stress at Yield (Offset 0.5 %) [MPa]
Heat cured	10	2805.779±245.604	37.575±1.272
CAD-CAM milled	10	2930.298±32.013	41.188±3.449
3D printed	10	2106.551±16.663	30.642±1.501
F(df)		95.98(2,27)	54.66(2,27)
p-value		0.000	0.000

[1] The one-way ANOVA was used. The significance level was established at 5%.
According to the descriptive results, the CAD-CAM samples group displayed greater Modulus coefficients as well as higher tensile stress parameters (Fig. 103).



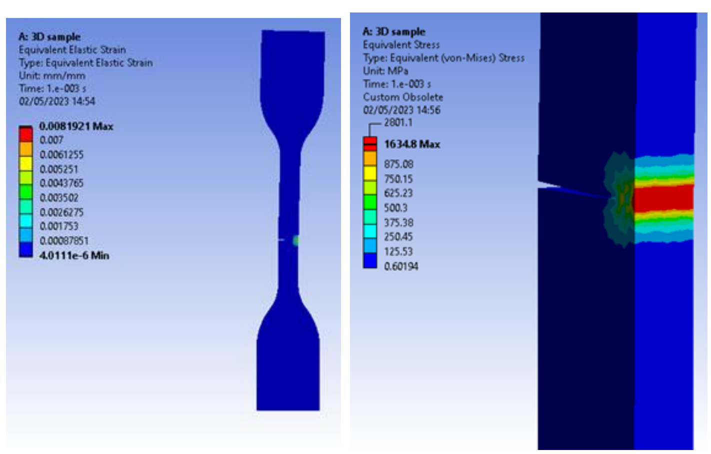
a. b.

Fig.103 Box plot of mechanical characteristics obtained by tensile tests by resin used: (a) Modulus; (b) Tensile stress at yield.

The one-way ANOVA also reveals a significant difference ($p<0.001$) in the mechanical characteristics between the three groups ($p<0.001$). Zooming in to each of the possible pairs, the Bonferroni test revealed that, when it comes to the Modulus coefficient, it is only the 3D printed samples which is on average different from the other two (p<p.0001). However, when looking at the tensile strength parameter, the statistically significant difference between the mean values is confirmed for all the three possible paired samples.

Finite element method (FEM) analysis
The contours of the samples show that critical points are at the ends of the fracture line and along all its length as the crack propagates. This type of result (Figure 104.a,b) is similar to the one observed in a real-life specimen that was subjected to a tensile test.

a



b.

Fig.104 Graphical representations of FEM results: (a) Front view of the equivalent elastic strain distribution along the fracture line; (b) Semi-side view of the equivalent (von-Mises) stress distribution along the fracture line.

Discussion

Based on the findings of this research, there were significant differences between the sample groups for all investigated characteristics, indicating that the study's null hypothesis was rejected. While 3D-printed samples recorded the highest surface roughness, heat-cured samples and CAD/CAM milled samples showed the lowest Ra coefficients, both before and after polishing. This discrepancy could be related to the manufacturing process of pre-polymerized resin blocks in subtractive technologies, as well as the reduced degree of polymerization in 3D printing.

Similar results were obtained by Helal et al. (Helal et al., 2022) significant differences between the tested denture base resins (3D-printed, CAD/CAM milled resin, and polyamide flexible resins). These findings are also supported by those obtained by the authors Zeidan et al. (Zeidan et al., 2022).

Srinivasan et al. conducted a study in which the surface roughness of CAD-CAM milled and rapidly-prototyped/3D-printed resins utilized in the fabrication of complete dentures was evaluated using a high-resolution white light non-contact laser profilometer (CyberSCAN CT 100, Cyber technologies, Eching-Dietersheim, Germany). Based on their findings, the authors concluded that both types of resins exhibited similar levels of surface roughness.

Contact testers, such as stylus profilometers, directly measure the height of surface irregularities and can provide highly accurate results. However, they can cause damage to delicate surfaces, are sensitive to vibrations and require a high level of operator skill to use properly. On the other hand, non-contact testers, such as laser and optical profilometers, are non-invasive, can measure surface roughness at high speeds, able to measure smaller asperity than contact types, simultaneous observation of surface image and height profile (microscope type) and able to acquire high-definition, fully focused images that rival those of SEMs (color 3D laser microscope) (Fu et al., 2018). However, they can be more expensive, require complex alignment procedures, the measurement area is limited, and they are for in-situ measurement.

The most significant effect of finishing on the micrometric profile was observed on 3D printed (ΔRa=0.445±0.027 μm) sample surfaces, while the impact was comparable in the CAD/CAM milled and heat-cured samples. Even though polishing improved the samples, they remained in the same order, with the 3D sample having the highest coefficients.

In a research, Freitas et al. (Freitas et al., 2022) showed that the surface properties of milled dentures are comparable to those of heat polymerized denture base resins, but with reduced Candida albicans adhesion. According to other authors, even after proper finishing and polishing and long-term thermocycling aging, traditional complete dentures were related with greater Candida adhesion than CAD/CAM milled prostheses.

Al Moaleem et al A(l Moaleem et al., 2022) and Ramage et al. (Ramage et al., 2012) reached the conclusion superior denture surface characteristics, such as porosity and surface roughness contribute to a reduction in microbial Candida adherence, lowering the incidence of denture stomatitis.

In their research, Paolone et al. (Paolone et al., 2020) emphasize the importance of denture surface quality in reducing bacterial plaque adherence and determining superior esthetics and excellent clinical results.

Regarding the mechanical parameters-hardness and tensile parameters, there were statistically significant differences between the groups. -Vickers hardness measurements found elevated values for the CAD/CAM milled experimental samples and the lowest values for the

3D-printed samples. The conventional heat-cured resin group recorded an average hardness value. Comparable findings were revealed in recent studies (Al-Dharrab et al., 2017).

The one-way ANOVA revealed a significant p-value when examining the statistical differences between the mean modulus and tensile stress values of the three groups (p 0.001). Comparing each of the potential pairs, the Bonferroni test revealed that, in terms of the modulus coefficient, only the 3D-printed samples differ from the other two on average (p .0001). When examining the tensile stress however, the statistically significant difference between the mean values is confirmed for all three potential matched samples.

The internal structures of materials determine their mechanical qualities, such as hardness and flexural strength. CAD/CAM milled polymers have a higher flexural strength than denture bases manufactured with compression molding, according to studies.
According to Srinivasan et al., milled resins have higher ultimate strength, toughness, and elastic modulus than printed resins while Al-Dwairi et al. (Al-Dwairi et al., 2019, Al-Dwairi et al., 2020), found that CAD/CAM milled denture base resins have a considerable advantage in surface wettability, surface roughness, and surface hardness.

Many studies indicated that the milled removable dentures demonstrated greater flexural strength, flexural modulus, and impact strength than typical heat-cured groups (Pacquet et al., 2019, Baba et al., 2021, Mubaraki et al., 2022, Abualsaudet al., 2022, Zeidan et al., 2023) as well as superior surface qualities compared to 3D-printed and conventional ones.

Acrylic resins for rapidly prototyped removable dentures have a poor double-bond conversion compared to standard heat-curing resins, which can impact their mechanical qualities. Unlike CAD/CAM milled resins, high pressure promotes the creation of longer polymer chains and can decide a greater degree of monomer conversion (Fouda et al., 2022). The lower characteristics of 3D-printed resin may be also attributed to the processing technique such as: light polymerization, printing method (layering technique and printing orientation), and parameters.

Steinmassl et al. got contradictory results, indicating that digital dentures do not generally have a higher fracture resistance compared to conventional prostheses made of self-curing or heat-curing resins. All CAD/CAM milled denture base resins have greater elastic moduli than heat- or self-curing resins. The fracture surface analyses imply that the microstructure of the resin, as opposed to the polymer chain length, which would be affected by the curing technique, may be accountable for the differing mechanical properties. They believe the changes in mechanical properties are due to the composition of the resin rather than the industrial procedure (Steinmassl et al., 2018).

According to the literature, CAD/CAM milled dentures have greater fit, surface qualities, and mechanical properties compared to traditional heat-polymerized dentures (Spagnuolo et al., 2020). Nonetheless, removable dentures fabricated with heat-cured resins remain a viable alternative since the mechanical characteristics and surface quality of these materials allow the manufacture of clinically well-tolerated prostheses. Being in direct contact with the oral tissues, all the new materials must be accurately tuned to fit the requirements and usage conditions (Drobota et al., 2022).

The FEA software predicted the correct propagation direction and offered valuable insight information in a graphical manner that can be used for future research. However, authors acknowledge the need for further refinement since our material mechanical properties may be different depending on the producer's manufacturing process.

Due to the lack of proper understanding on the biomechanical principles of the materials involved in restorative procedure, lead too many detrimental effects causing a restorative failure. Therefore, in order to know the behavior of materials and dental tissue, biomechanical studies are very crucial. The limitations of the current research were the lack of denture base materials, the absence of oral conditions simulation, and that the samples weren't aged by thermocycling. Given these constraints, further in vitro and in vivo studies are required.

Conclusions

The study is based on three different groups of specimens which gave us 90 samples to test. Every ten samples had two more that were used for validation purposes.

Each sample proved consistent within limits, thus proofing our results. Out of the three, the 3D printed samples ex-perience the lowest surface quality in terms of surface finishing and structural integrity.

The homogeneity of materials is affected by the process of choice. CAD-CAM produces smoother results but not necessarily better when observed at microscopic level. Resin based heat pol-ymerized samples show a similar surface finish as milled ones do. However, they are less prone to bacteria adhesion due to the heat treatment and UV curing.

Milled samples exhibit superior mechanical properties as the internal structure of the material is not altered by external factors such as heat rearrangement as it is the case for temperature dependent resins or light polymeri-zation and layer disposition as it is the case with 3D printing.

As other authors stated, the pro-cess of obtaining the samples plays a significant role in their mechanical assessment rather than material's chemical composition. Studies show that heat treated resins are well tolerated by hu-man body followed up close by 3D printing if further processing is performed.

Finite element analyses predicted a similar behavior for the crack propagation as real-life samples showed if the concentrator is placed in the same area.

Statistically, ANOVA highlighted different values for the 3D printed samples on average compared to the others. Despite CAD-CAM advantages, heat-cured base resins and 3D printing have potential to be a valid substitute due to their similar mechanical properties but better human body acceptance and bacteria resistant properties.

Polymerization plays a significant role through its ability to rearrange atoms inside the material which results in long-term durability.

Although 3D printing sets itself as an alternative it still requires further refinement which makes it suitable for provisional or emergency procedures only. Authors acknowledge the need for further refinement of results and wider research base.

Chapter 4

POSSIBILITIES AND LIMITS OF CROSS-INFECTION CONTROL IN THE DENTAL LABORATORY

State of art

Dental technicians, during their activities, are exposed to a series of noxious factors, which might affect their health. The Occupational Information Network, a US Department of Labor database, conducted a study to rank the „Most Unhealthy Jobs" in America. They analyzed the health risks in each of the 974 occupations in the database using criteria such as exposure to radiation, contaminants, infections, and time spent sitting, with scores of these factors on a scale from 0-100, with a higher score indicating an increased health risk. Dental profession ranked number 1 as the unhealthiest job of all 974 occupations in this study (American Dental Association Council on Scientific Affairs and ADA Council on Dental Practice. Infection control recommendations for the dental office and the dental laboratory; Vázquez-Rodríguez et al., 2018).

Dental laboratory technicians are exposed to numerous pollutants that could cause occupational diseases in the medium or long term, such as bronchitis, asthma, silicosis and other respiratory complaints (Gupta et al., 2017, Ozdemir et al., 2010, Rasam et al., 2015).

Exposure occurs during handling the refractory investments, sandblasting of metallic parts and finishing operations.

Dusts of non-precious alloys (very often used dental technology) are extremely toxic and can cause allergic symptoms, respiratory complaints, dermatological problems and neurotoxicity among dental technicians (Sedky et al., 2019)

Each stage of the technological algorithm can involve the inhalation of a number of harmful substances (Diaconu D et al., 2012). Several cases of respiratory problems have been reported among dental laboratory stuff and epidemiological studies have shown a high prevalence of pneumoconiosis related to combined exposure to several contaminants and their period of action.

Metals, waxes, resins and silica can cause irritation or allergic reactions, affecting the skin and the respiratory system, as well. The risks of benign pneumoconiosis induced by hard metals are well documented, a prevalence of 15.4% after 20 or more years of exposure being reported, whereas the prevalence in the general population is less than 1% (Diaconu-Popa et al., 2018, Belkıs et al., 2015, Lang et al., 2018). Malignant pneumoconiosis is caused by dust from crystalline silica, asbestos or beryllium. Silicosis is the most common occupational disease among dental technicians, and isolated cases of systemic autoimmune diseases have been observed (Verran et al., 2004, Vafaee et al., 2013).

Contaminated invisible aerosol particles remain in the air for a long time after using lathes for the polishing of prostheses. The rotation speeds of engines are usually high, thus generating very fine powders, whose pathogenicity depends on the particles size, concentration, composition, and duration of exposure (Thomas et al., 2013).

The smoke released during the wax burnout stage, contains mainly colophonyknown as an allergic substance that may cause asthma. In most cases, the processed pieces are also microbial contaminated, so that their pathogenic potential is even higher. Therefore all these chemical agents (gases, vapors, powders), have an irritating or carcinogenic action. Because it not possible to eliminate all sources of contamination in the laboratory, a series of prevention measures should be taken in order to avoid the professional diseases. Dust from processing prosthesis parts is often microbial contaminated. Motor rotation speeds are typically high, thus generating very fine powder, usually less than 5 microns, which penetrate pulmonary alveoli (Firoozeh et al., 2013, Williams et al., 2011).

Harmfully potential is conditioned by particle size, concentration, composition, time exposure (often more than ten years). There are numerous studies that analyse the microbial air in dental offices and the contamination risk due to trespassing strictly prophylactic rule (Hallier et al., 2010, Chatterjee et al., 2021). Protocols for dental offices activity provide air decontamination using germicidal generating ultraviolet radiation lamps. Approximately 95% of the radiation have germicidal wavelength of 253, 7 nm. The remaining 5% is the radiation wavelength of 184.9 nm, producing ozone effect also germicide. Time for action indicated is 20 minutes. The contamination risk throughout the activities conducted in the dental laboratories raised specialist's interest, especially in the last years, because in this segment of the dental algorithm the cross-infection risk is still high (Balcos et al., 2018, Kilimo et al., 2016). If in the dental praxis the asepsis and antisepsis rules are very strict, and the instrument circuit is well documented (The Ministry of Health Order no.349 from 11 April 2005.), for the dental laboratories strict regulations are still absent. Research shows that the tools used in processing and pastes for polishing prostheses are important sources of contamination. All these studies confirm the need to establish strict rules regarding the circuit of fingerprints and prosthetic parts, in order to minimize the risk of contamination of staff and patients during the clinical-technological algorithm.

In this sense, several steps must be followed:

I. Detection the contamination sources

- impressions and prosthetic elements
- dental laboratory instruments
- contaminated powders

II. Reducing the risk of contamination

-contamination control in the dental office
-hygiene measures of laboratory staff
-effective communication between the dental office and the laboratory

III. Development of a guide with prophylactic measures, for:

-protection of patients and members of the dental team
-reducing the number of pathogens in the workspace
-implementation of a high standard in the control of cross-infection, which allows the protection of each patient.

In the absence of a rigorous control of the work circuit there will be a potential risk for the dentist, following the handling of contaminated parts from the laboratory and a risk for laboratory staff, which can be contaminated by direct contact with the prostheses checked in the oral cavity or by inhalation or ingestion of contaminated powders resulting from the finishing and polishing of the prosthetic elements (Sacoor et al., 2020, Ataei et al., 2019).

The risk of contamination during the work in the dental laboratories has attracted the attention of specialists, especially in recent years. If in dental offices the rules of asepsis and antisepsis are certainly established and the instrument circuit is rigorously controlled, in dental laboratories the risk of cross-infection still exists (Yadav et al., 2017, Ch et al., 2018, Lamb et al., 2019). Infection control is an area of dentistry, which is associated with an increased risk of transmitting the infection through direct or indirect contact with contaminated elements (Banglani et al., 2016).

Dental laboratory personnel are at risk for infection transmission by the same mechanisms as other dental healthcare professionals (Patel, 2020). The firs goal of infection control is to minimize the spread of infection by breaking as many links in the chain as possible. In the dental laboratory, this would incorporate adherence to principles of aseptic technique, appropriate immunizations for laboratory staff, the use of barrier techniques, and implementation of standard precautions. Standard precautions dictate that all laboratory cases are handled the same way and are treated as if contaminated and infectious. Knowing the sources of contamination in dental laboratories allows a correct assessment of the risk of cross-infection and the consequences on patients, dentists and dental technicians.

The protection of the dental team in the dental laboratory considers the protection of the visual analyzer, protection of the auditory analyzer, protection against vibration, protection against dust, gases, acids, antimicrobial and antiviral protection, protection against hypokinesia, protection against ionizing radiation, protection from electrical installations, or natural gas (Inayati et al., 2021, Rodrigues et al., 2013). Antimicrobial and antiviral protection is the fundamental objective of dental activity on which the safety of staff (doctor, dental technician, patient) depends. Laboratory personnel must wear a bathrobe, mask, gloves, goggles; also, it must be rigorously disinfected the furniture, equipment, surfaces and instruments in the laboratory with adequate solutions (glutar-aldehyde, formaldehyde, ethylene-hexanol alcohol). Decontamination of fingerprints, models, diagnostic models, color keys, temporary prostheses, decontamination of articulators and facial arches should not be neglected (Samejo et al., 2018)

The evaluation of the conditions for carrying out the activity in the dental technique laboratories regarding the application of the infection control protocols demonstrates the need to implement energetic measures to increase the level of knowledge in this field. The organization of medical education actions and the initiation of specific programs must aim at increasing the compliance of dental technicians with the control measures of cross-infection.

My contributions to this research direction can be found in the following articles:

1**. Diaconu D,** Vitalariu A, Tatarciuc M, Murariu A. The economic crisis effects on the cross contamination control in dental laboratories. *Revista de cercetare și interventie social*ă 2014; 47:105-116. IF=0,798.

2. **Diaconu-Popa D,** Tatarciuc M, Viţalariu A. Evaluation of the air quality in dental laboratory. *Romanian Journal of Oral Rehabilitation* 2018; 10(3):142-146.

3.**Diaconu D,** Tatarciuc M, Viţalariu A. Quantitative analysis of bacterial contamination in dental laboratory air, Romanian Journal of Oral Rehabilitation 2012; 4(4): 27-29.

4. **Diaconu D,** Tatarciuc M, Viţalariu A. Determination of the concentration of respiratory powders in dental technique laboratories. *International Journal of Medical Dentistry* 2011, 15(4):382-385.

5. Tatarciuc M, Zamfirache I, Marius S, Vitalariu AM**, Diaconu D.** Microbiologic study regarding the risk of cross infection in the technical laboratory. *Analele ştiinţifice ale Universităţii Al.I.Cuza,* Secţiunea Genetică şi Biologie Moleculară 2010; XI(4): 53-58.

1. RESEARCH ON THE KNOWLEDGE AND IMPLEMENTATION OF MEASURES TO CONTROL CROSS-INFECTION IN THE DENTAL LABORATORY

Introduction

Numerous studies have shown that in the dental laboratories the transmission of microorganisms takes place by means of impressions received from the dentist, and by processing of acrylic dentures and prosthetic devices which come back to the lab, after they have been checked or adapted in the patient mouth. In the literature, researchers show that 9 out of 10 prosthetic devices sent completely sterile from the dentist were contaminated after their processing in the lab with microbial germs that do not belong to the oral saprophyte flora and which may cause serious diseases for patients (American Association of Public Health Dentistry, 1986). For these reasons, it is mandatory to decontaminate all prosthetic devices coming in the lab from the dental office and any prosthetic device leaving the laboratory must also be disinfected. Another important source of contamination in the dental laboratory, overlooked by dental technicians, is represented by the wheels and pumices used in the finishing and polishing process (Naz et al., 2020, Hakam et al., 2018, Gray, 2105).

The aim of this study is to highlight the degree of knowledge of prophylactic measures in the dental laboratory and to analyze how these standards are implemented in current practice.

We also centralized the attitude of dental technicians towards the application of prophylaxis measures and their opinion on the impact on the additional costs imposed by these measures.

The results of on the knowledge and implementation of measures to control cross-infection in the dental laboratory are illustrated by the following publications:

1. **Diaconu D**, Vitalariu A, Tatarciuc M, Murariu A. The economic crisis effects on the cross contamination control in dental laboratories. *Revista de cercetare și interventie socială* 2014; 47:105-116
2.Melinte A, Diaconu Popa D, Vitalariu A, Tatarciuc M, Luchian D. Measures to prevent contagious diseases in the first half of the nineteenth century. *Romanian Journal of Medical and Dental Education* 2018; 7(2):101-106.
3. Diaconu D, Tatarciuc M, Viţalariu A. Quantitative analysis of bacterial contamination in dental laboratory air. *Romanian Journal of Oral Rehabilitation* 2012; 4(4): 27-29.

Matherial and methods

First step was to quantify the knowledge and practices in infection control among dental technicians working in commercial dental laboratories in Iasi and also to analyse if they consider that the prophylactic measures would involve some unjustified additional costs in their activity.

To perform this research, we used a questionnaire containing 13 questions conceived by the authors. The questionnaire was divided into two sections: the first section containing 9 questions focuses on the testing of knowledge of dental technicians regarding the control measures of crossed infection; the second section containing 4 questions evaluates whether the observance of prophylactic measures has imposed additional expenses in the context of the economic crisis. The questionnaire was pilot-tested by distributing it to twenty dental technicians who work in or collaborate with our university dental clinic. The answers to the pilot test were analyzed to assess the clarity and relevance of the questions, and modifications were made. After receiving feedback from pilot test participants, it was sent to 26 laboratories of Iasi. The study was conducted between August-October 2013.

Data were analyzed with the SPSS 17.0 system for Windows (SPSS Inc. Chicago, IL, SUA). Variations in distributions of the answers were analyzed by cross tabulations. Statistical significance of the bivariate analysis was assessed by the Pearson chi-square, at the 0.05 level. Correlations between different questions were determined by Pearson correlation coefficients.

If in the dental offices, asepsis and antisepsis rules are clearly established andthe circuit of instruments is strictly controlled, the risk of cross-infection is still present in the dental laboratories.

Results

Following the distribution of questionnaires regarding the analysis of the level of prophylaxis knowledge and implementation of these measures in current practicewe received 108 answers out of 113 representing an answer rate of 95.57%. Dental technicians who participated in the study were divided into three lots depending on their length of service in the dental lab: 38 of them had less than one year length of service (35.2%), 33 respondents had the length of service between 1 and 5 years (30.6%), and 37 technicians had a length of service over 5 years (34.3%).

The returned questionnaires were reviewed for completeness and statistically analyzed. In the first stage of statistical processing, the univariated descriptive analysis has been used in order to calculate the percentage of responses to the survey questions (Table XXIX), and the bivariate analysis to explore existing relationships between two variables, namely the survey questions that make reference to the economic crisis in relation to length of service (Table XXX).

From the dental technicians' answers we noticed that 95.4% are aware of the real risk of contamination correlated to the surfaces and instruments in the lab.

The same high percentage of 95.4% represents those who are aware of the high risk of crossed infection having as a vector all the prosthetic devices coming from the dental office or leaving the laboratory.

Answers to question no. 3 about the rendering sick of the lab personnel through the handling of contaminated prosthetic devices were affirmative for 92.6% of respondents.

A reduced percentage of 47.2% consider only impressions as the most important source of contamination, whereas 63% think that all devices coming from the dental office must be disinfected by the technician (question 5). A similar percentage was obtained for question no. 6 where 64.8% declared that the same devices must be disinfected as well when they are sent back to the dentist.

A well known aspect regarding decontamination methods is the disinfection of lab surfaces sustained by the percentage of 90.7% of those who answered question no. 7. At the opposite end there is the reduced knowledge of technicians about the air decontamination methods, and this is supported by the fact that only 38% of them do this every day (question no. 8), and in the context of reduction of lab budget 75% would give up this procedure (question no. 13). Wearing protective equipment (gloves, glasses) is a daily routine for 55.6% of respondents whereas 37% sporadically use these prevention measures (question 9).

Table XXIX. Survey questions

Question	Answer	Number	%
1.It is possible to contaminate surfaces and instruments in dental laboratory	a. YES b. NO c. I dont't know	103 5 0	95.4 4.6 0
2. There is a risk of contamination for prosthesis/prosthetic parts sent from lab to dental office?	a. YES b. NO c. I dont't know	103 5 0	95.4 4.6 0
3. There is a risk of contamination for dental aboratory workers?	a. YES b. NO c. I dont't know	100 6 2	92.6 5.6 1.9
4. What do you think are the sources of contamination? Specify some of them.	a.impressions b. prosthesis c. everything d. I don't know	51 2 48 7	47.2 1.9 44.1 6.5
5. What pieces received from the dental office should be disinfected in the lab?	a.impressions b. prosthesis c. all d. I don't know	35 1 68 4	32.4 0.9 63 3.7
6. What pieces sent to the dental office should be disinfected in the lab?	a.impressions b. prosthesis c. all d. I don't know	2 30 70 6	1.9 27.8 64.8 5.6
7. Do you consider necessary the disinfection of the laboratory working tools	a. YES b. NO c. I dont't know	98 9 1	90.7 8.3 0.9
8. Do you perform surfaces and air decontamination every day?	a. YES b. NO c. I dont't know	41 55 12	38 50.9 11.1
9. Do you wear protective equipment (gloves, goggles) during maneuvers	a. YES b. NO c. Sometimes	60 8 40	55.6 7.4 37

Table no XXX Questions about additional costs

Question	Answer	Number	%
10. Do you try to reduce the costs by changing polishing pastes and brushes at larger intervals of time?	a.I change them daily b. I change them weekly c.I change them after each use d. I don't know	6 81 10 11	5.6 75 9.3 10.2
11. Do you consider an additional financial effort using the cross-infection preventing methods?	a.YES b. NO c. I don't know	34 61 13	
12. You consider that the economic context of recent years imposed spending reduction regarding preventing methods?	a.YES b. NO c. I don't know	26 56 24	24.1 53.7 22.2
13. Which contamination prevention methods you could give in order to reduce the laboratory costs?	a. mask, gloves, glasses b. surfaces decontamination c. air decontamination d. none	10 1 81 16	9.3 10.8 75 14.8

The last four questions focus on the economic side of the activity in the dental laboratory due to the reduction of expenses in the context of decrease of clinical handworks.

Most respondents (75%) answered question 10 regarding the interval for changing the denture pumice saying that they do this every week, 5.6% daily and 9.3% after each use. 31.5% of technicians consider the application of all prevention methods as a supplementary financial effort, whereas a higher percentage 56.5% affirms that this does not represent a financial burden (question 11). In connection with the context of economic crisis, 53.7% answered negatively the question about the need to reduce the expenses allocated to the prevention methods (question 12). If the lab expenses were to be reduced, 14.8% declared that they would not give up these procedures. Answers to question no. 11 demonstrate that most technicians do not consider these prevention methods as an additional financial effort (50% of those having a length of service within one year, 57.6% having the length of service between 1 and 5 years and 62.2% having a length of service over 5 years), and the differences identified do not have a statistic significance p=0.531. As for the reduction of lab budget, only 34.2% of those having a length of service within one year and 28.9% of those having a length of service over 5 years declared that they also reduced the expenses related to these decontamination methods (question no. 12).

Most answers belonged to those who declared that they have reduced the lab expenses, the highest percentage belonging to those having the length of service between 1 and 5 years (63.6%) followed by the young ones 36.8%, and finally 24.2% of the old ones. The differences identified for the 3 age groups have statistic significance (p=0.005). The methods for infection prevention (question no. 13) which they would give up are, for most categories of length of service, the ones used for air decontamination: 57.9% for the group having a length of service within one year, 90.9% for the group having the length of service between 1 and 5 years and 78.4% for those having a length of service over 5 years. Only 3% of those having the length of service between 1 and 5 years would give up the methods for surface decontamination. The differences identified have statistic significance, p=0.023

Besides the descriptive statistics analysis, by means of cross tabulations and Chi-square test we made a differentiation of answers to questions referring to the effect of economic crisis depending on the length of service. As for the sparing of pumice and wheels (question 10), most dental technicians, regardless of their age, declared that they do this once a week. We have noticed statistically significant differences p=0.005 in terms of the daily change of pumice and wheels within the meaning that the highest percentage (21.1%) belongs to those having the length of service within one year as compared to the elderly ones who perform this activity every day in a percentage of only 5.4%. At the opposite end, there were the ones having the length of service between 1 and 5 years since no technician of this group declared anything about this aspect. (Table XXXI).

From Pearson correlation analysis, we may notice a strong association between the answers obtained for questions 11 and 12, r=0.459, p=0.01. This aspect demonstrates that the methods dedicated to contamination prevention (question no. 12) represent, in the current context of economic crisis, an additional financial effort for the dental laboratory (question no. 11). The same positive correlation with statistic significance has been noticed between the answers given for questions 11 and 13, but with a lower intensity, r=0.350, p=0.01.

The results of Pearson analysis show that out of the same financial motivation some technicians are ready to give up certain methods for crossed infection prevention (question no. 13), one of these being the daily decontamination of surfaces (question no. 8).

Table XXXI. Pearson correlation significance

Questions	Answers	< 1 year (%)	1-5 years (%)	> 5 years (%)	p value; Pearson chi-square value (χ^2)
10. Do you try to reduce the costs by changing polishing pastes and brushes at larger intervals of time?	a.I change them daily b. I change them weekly c.I change them after each use d. I don't know	2.6 65.8 21.1 10.5	9.1 90.9 0 0	5.4 70.3 5.4 18.9	p=0.005 χ^2=18.47
11. Do you consider an additional financial effort using the cross-infection preventing methods?	a.YES b. NO c. I dont't know	31.6 50 18.4	30.3 57.6 12.1	32.4 62.2 54	p=0.531 χ^2=3.165
12. You consider that the economic context of recent years imposedspending reduction regarding preventing methods?	a.YES b. NO c. I dont't know	34.2 36.8 28.9	12.1 63.6 24.2	28.9 24.2 13.5	p=0.005 χ^2=9.372
13.Which contamination prevention methods you could give in order to reduce the laboratory costs?	a. mask, gloves, glasses b. surfaces decontamination d. none c. air decontamination d. none	15.8 0 57.9 26.3	3 3 90.9 3.1	8.1 0 78.4 13.5	p=0.023 χ^2=15.854

The association identified has a statistic significance and a lower correlation coefficient, r=0.303, p=0.05 (table XXXII).If in the dental offices, asepsis and antisepsis rules are clearly established and the circuit of instruments is strictly controlled, the risk of cross-infection is still present in the dental laboratories. Our researche demonstrated that only 63% of technicians decontaminate all the prosthetic devices coming from the dentist, impressions occupying the first place as contamination vectors in a percentage of 47.2%.

The results obtained are similar to the percentage obtained other studies carried out in 2011 in Iasi (Barlean et al., 2011).

Table XXXII Pearson correlation analysis.

	Changing pumices/brushes at larger interval; of time(10 hours)	Additional efforts (11)	Reducing costs (12)	Quit preventive measures (13)	Wear protective equipment (9)	Daily decontamination (8)
Changing pumices/brushes at larger interval; of time(10 hours)	**1.000**					
Additional efforts (11)	**.064**	**.1000**	**.**			
Reducing costs (12)	**.125**	**.459****	**..1000**			
Quit preventive measures (13)	**.105**	**.350****	**.073**	**.1000**		
Wear protective equipment (9)	**.072**	**.080**	**.038**	**-.134**	**1.000**	
Daily decontamination (8)	**.101**	**.281***	**.094**	**.303***	**.085**	**1.000**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Discussions

Both practitioners and researchers have been constantly concerned with detecting sources of contamination in the dental office and dental laboratory, wanting to establish a set of prophylactic measures to prevent cross-infection (Kohn WG et al., 2016; Debattista N et al., 2007). There are studies that show that over 60% of the impressions arrived from dental offices in the dental laboratories are contaminated with Enterobacter cloacae, Escherichia coli, Klebsiela oxytoca (Barenghi L et al., 2019; Pankhurst CL et al., 2017; Barenghi L et al., 2018)

Although microorganisms transition can be carried out by the impressions received from the dentist, there are a few studies that also incriminate the processing of the denture or the intermediate prosthetic parts that were verified or adapted in the oral cavity of the patient (Schierz O et al., 2021; Bensel T et al., 2013; Agostinho AM et al., 2004; Nair VV et al., 2016)

Disinfection is usually done by the immersion method, which has the advantage of allowing full coverage of surfaces, so it achieves effective decontamination, but there is a risk of changing the size of certain prosthetic parts (Pradhan D et al., 2019;. Sedky NA et al., 2014; Al-Mortadi N et al., 2019). For disinfection by spraying method there is a range of products is narrower and there is a risk of incomplete coating of surfaces and removal of disinfectant particles in the air.It is extremely important that the substances used for decontamination have an effective antibacterial effect and do not affect in any way the accuracy of the prosthetic part.

Although there have been concerns in this field for many years, the lack of concretization of the results as a direction of practical application is lacking, so that the realization of a guide of unitary measures to be observed in all dental work units is an extremely useful measure.

Evaluation of the development conditions of activity in dental laboratories regarding the application of dental protocols infection control demonstrates the need to implement measures to increases the level of knowledge of the staff.

In the dental laboratories, the procedures for cross-infection prevention focus on the following aspects: protection barriers against the microbial germs (gloves, mask, and glasses), decontamination measures for impressions, instruments and lab air and the immunization of the lab personnel against hepatitis B virus. In this study, we have noticed that only 55.6 % of technicians regularly use gloves, protection glasses and mask.Other researches in the field show that in the labs from the Great Britain, 44% of technicians wear gloves and 74% wear glasses, unlike the technicians from Jordan where only 24% of technicians wear gloves and 35% wear a mask.

In Romania, the results of the study published by Barlean et al, in 2011, demonstrated that only 49.1% of technicians use protective equipment. From the correlation analysis carried out, we have noticed that there is a positive association and with strong intensity ($r=0.459$, $p=0.01$) between the answers for questions focusing on the possibility to give up the decontamination methods considered as an additional financial effort (questions 11 and 12).

Although they are not in a high percentage, still the fact that 34.2% of those having a length of service within one year declared that they may give up decontamination represents an alarm signal in order to introduce these very important aspects for the public health in the conduct of young technicians as early as their academic studies. A third of them also declared that they would easily give up these procedures because they require supplementary funds. Also serious is the fact that a high percentage of 75% would give up the methods for lab air decontamination requiring the purchase of special equipment. Depending on their length of service, we have noticed statistically significant differences within the meaning that 90.9% of those having the length of service between 1 and 5 years declared that they give up this procedure unlike those having a length of service within one year whose percentage is lower, 57.9%. Otherwise, for this age category, we noticed that a very low percentage of only 3.1% would not give up any method for crossed infection prevention.

These answers suggest an insufficient knowledge of the issues and require the increase of the knowledge level by post-academic courses and continuous profes sional training.

Our studie's results along all the others, confirm the necessity of a set of strict regulations, regarding the impressions and prosthetic devices circuit, in order to reduce the contamination risk of both medical personnel and patients, throughout the clinical-technologic algorithm.

Although we found that most technicians (95.4% of respondents) are aware of the existence of a real contamination risk both of the lab surface and the personnel, however we have noticed a decreased vigilance when they are forced to reduce the lab budget. On the other hand, we have noticed a reserved attitude towards certain decontamination methods considered unnecessary, such as those addressing the air decontamination, 75% of respondents declaring this aspect.

The measures of personal protection do not represent a permanent need for 37% of respondent technicians which means that, although theoretical notions are known, they are not always put into practice.

In the same line are the answers given for the question regarding the daily decontamination where only 38% of technicians answered affirmatively.

That is why we consider important the organization of practical courses for the reevaluation of knowledge and behaviour towards the standard procedures for infection control in the dental laboratory.

Depending on their length of service corroborated with the effects of budget reduction, the analysis carried out demonstrates the existence of some statistically significant differences between the three age groups. Thus, we have noticed that the reduction of expenses determined by the economic crises is higher for those having a medium length of service as compared to the younger or older ones, and they also represent the lowest proportion of technicians who would not give up the methods for crossed infection prevention, regardless of the existing financial effort.

In contrast to the dental treatment rooms and surgical operatories where infection control measures are rigidly recommended, the dental laboratories are often overlooked. This constitutes a threat to the safety of dental technicians, who may acquire pathogenic microorganisms from contaminated impressions, prosthesis, and/or by improper handling of clinical materials after arrival at the dental laboratory gupta et al., 2017).

The principal route of transmission of infection from the patient to the dental technician is through these materials as they are in direct contact with patient's mouth, saliva, and possibly blood. It has been documented that dental personnel have a 5–10-fold chance of acquiring hepatitis B infection than the general population (Kohli ety al., 2007)

The role of these researches is, on the one hand, to detect the sources of contamination, to eliminate them and to make the staff in dental technical laboratories aware of the risks to which they are exposed.

Conlusions

As a conclusion, in the current conditions of reduction of the lab expenses caused by the lack of addressability to dental services, we notice an alarming aspect, namely the giving up on some decontamination methods (air, surfaces, and devices) in the dental laboratory. This is not necessarily due to the lack of theoretical knowledge, but especially to the lack of concern for the implementation of these measures. Dentures processing using instruments and polishing paste that were used before in other operations, as well as handling them, accounts as the main microbiological contamination sources along the work algorithm conducted in the dental laboratory. Also the old polishing paste can be considered an important vector in the contamination of the denture.

The future elaboration of a good practical guide, which will be implemented in all dental work units, is well supported by the conducted microbiological analysis, being a necessary and welcome measure.

These conclusions will contribute in the future to developppe a practical guide for preventive measures and to establish strict rules of asepsis and antisepsis along the clinical algorithm.

2. RESEARCH ON POWDER LOADING AND THEIR MICROBIAL CONTAMINATION IN DENTAL LABORATORY

Introduction

Technological algorithm in prosthesis construction achievement involves a variety of stages, after which appears both: pollution and contamination in atmospheric air, which can cause serious health damage in all dental team members. Dental technicians, during their professional activity, contact several harmful factors and their harmful effects depending on toxic concentration in air and exposure in time. Studies to date indicate that the most common diseases in dental technicians are located in respiratory system and consist of silicosis, berylliosis, interstitial pneumonia, pulmonary fibrosis, asthma, chronic obstructive bronchopneumopathy, allergic respiratory reactions, reduced respiratory capacity, and emphysema. Dust generated by processing prosthesis parts is often microbial contaminated. Motor rotation speeds are typically high, thus generating very fine powder, usually less than 5 microns, which penetrate pulmonary alveoli. Harmfully potential is conditioned by particle size, concentration, composition, time exposure (often more than ten years) (Sykes et al., 2019, Vafaee et al., 2013).

The aim of the study was to evaluate the amount of powders produced into dental laboratories, to corroborate the obtained results with the conclusions of other investigations developed by the same team, for the elaboration of a practical guide of the main prophylactic measures to be taken. The study develops a quantitative analysis of the respiratory powders present in the laboratory of dental technique, without determining the nature or prevalence of each pathogenic agent and to determine thei microbial load.

The results of studies on powder loading and their microbial contamination in the dental laboratory are illustrated by the following publications:

1. **Diaconu-Popa** D, Tatarciuc M, Viţalariu A. Evaluation of the air quality in dental laboratory. *Romanian Journal of Oral Rehabilitation* 2018; 10(3):142-146.
2.**Diaconu D**, Tatarciuc M, Viţalariu A. Quantitative analysis of bacterial contamination in dental laboratory air, *Romanian Journal of Oral Rehabilitation* 2021, 4(4):
3 **Diaconu D,** Tatarciuc M, Viţalariu A. Determination of the concentration of respiratory powders in dental technique laboratories. *International Journal of Medical Dentistry* 2011, 15(4):382-385.

Materials and methods

For the determination of the amount of powders, produced in the laboratory of dental laboratories, air samples have been taken over, for 8 hours, along 10 days, from three spaces of the laboratory of dental technique, namely: the room of fixed prostheses, the room of ceramics and the processing room.

Respiratory powders have sizes below 10 microns, while the maximum values accepted in the atmosphere are of 10 mg/mc.

Determination of powders' concentration in air was made HPC601 laser particle pumps, placed in each room, in the vicinity of the working space. On each pump, a (previously weighed) paper filter was mounted, the pumps being set at a 5 l/min flow, at constant temperature of 24°C.

The obtained values were statistically analyzed in the Department of Informatics of the Faculty of Medical Dentistry, by means of the IBM SPSS Statistics 25 program, in cooperation with the Department of Medical Informatics and Biostatistics of the U.M.Ph.Iasi

For the microbial evaluation we used the Koch method. Their inoculation was done on preformed solid culture medium, based on agar-agar, in opened and exposed Petri dishes with a diameter of 90 mm.

Five samples were placed in various working areas of dental laboratory; first samples were left uncovered for 15 minutes at the first hour in the morning. Next group, also consisted in five samples, was obtained during specific working steps. The last five samples were recorded at the end of working day.

After exposure, the Petri dishes were sealed and sent to the microbiology laboratory. Samples were incubated for 24 hours at 37ºC, and then were allowed for additional 24 hours at room temperature and light exposure. Colonies were counted starting from the premise that each colony has grown from a microorganism, and by counting all colonies, we obtained the total number of bacteria. The method used is simple and allows simultaneous multiple determinations, thus achieving very accurate characterization of air contamination.

To express the microbial load per unit air volume, Omeliansky formula was used, which calculate the germs from 10 litters of air deposed on a surface of 100 cm^2 in 5 minutes:

Number germs/ air m^3n X 10000: S T/ 5, n being the number of colonies developed on culture medium surface, S the Petri dish surface in cm^2, and T being the time of exposure, in minutes.

Results

For the second stage of the study, the analysis of the powder charge of the air from the dental technique laboratory, we centralized the information obtained after collecting the samples.

The data registered for the first working room – the laboratory of fixed prostheses – were systematized in view of a subsequent comparative analysis (table XIII):

Table XXXIII. Data registered for the first working room

Room	**Laboratory of fixed prostheses**									
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
µg/m³	**0.7**	**1.2**	**1.3**	**1.1**	**2.3**	**1.3**	**0.9**	**0.9**	**1.41**	**1.7**

The listed values show that the highest amount was of 2.3 µg/m³, the lowest one being of 0.7 µg/m3 (fig.105).

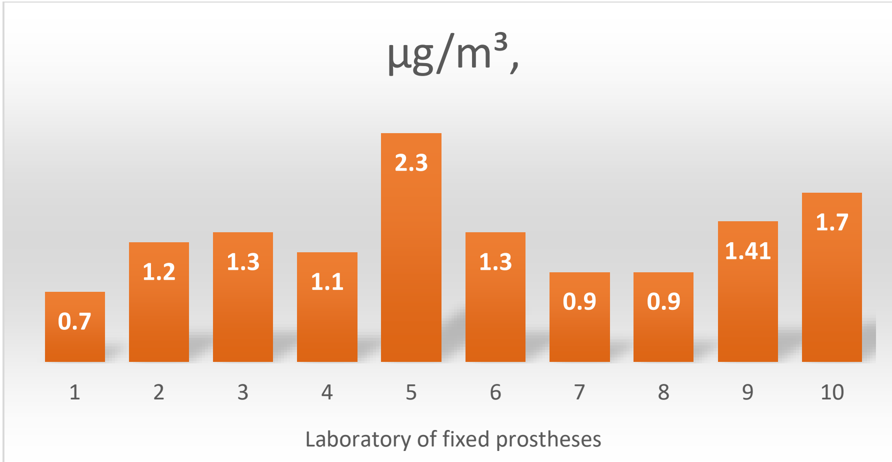


Fig. 105 Values obtained for respiratory powders in the first working room

For the ceramic room, the maximum values obtained were of 1.7 µg/m³, while the minimum ones were of 0.2 µg/m³ (Table XXXIV).

TableXXXIV The data registered for ceramic room

Room	**Ceramics laboratory**									
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
µg/m³,	**0.7**	**0.2**	**0.3**	**0.2**	**1.7**	**0.3**	**0.2**	**0.2**	**0.6**	**0.4**

The maximum registered amount is lower than in the first working room (fig. 106).

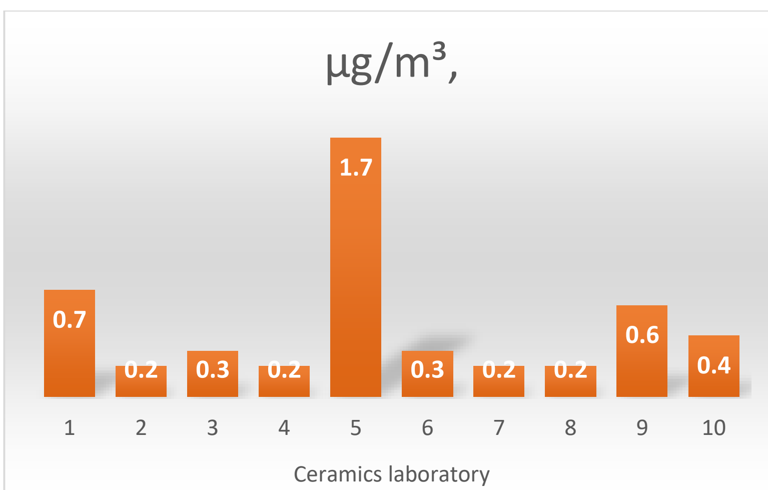


Fig. 106 Values obtained for respiratory powders in the second working room

In the finishing and polishing room, the highest value was of 3.7 µg/m³, and the lowest one – of 0.9 µg/m³ (table XXXV).

Table XXXV. The data registered for the polishing room

Room	**Finishing and polishing laboratory**									
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
µg/m³,	**0.9**	**1.8**	**2.3**	**1.5**	**3.7**	**3.2**	**2.9**	**1.8**	**2.1**	**2.6**

The above data show that, in this room, the maximum value is higher than in the others, which is also the case of the minimum value (fig.107).

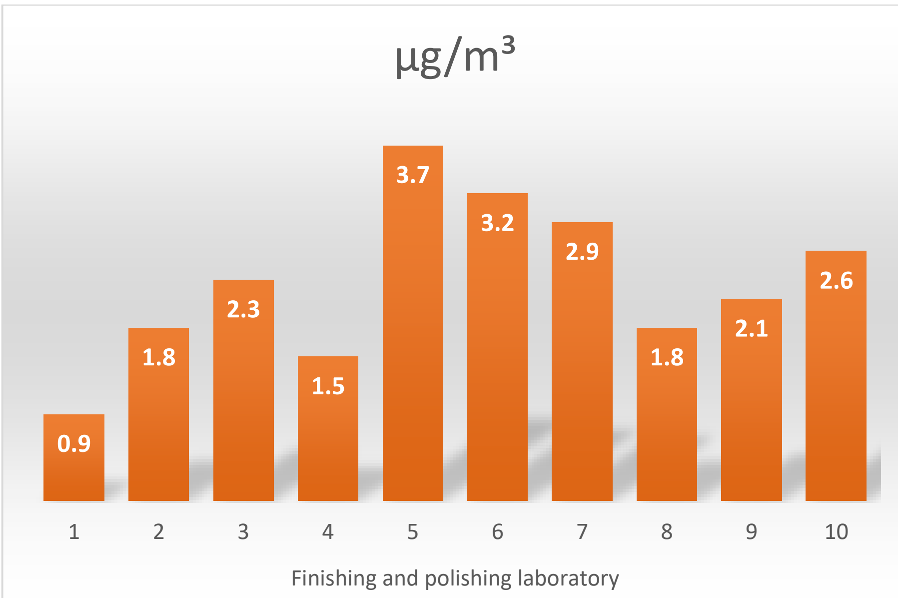


Fig.107 Values obtained for respiratory powders in the third working room

For a subsequent comparative analysis, the values obtained in the three working spaces were systematized in table XXXVI.

Table XXXVI. Data centralized for the three working rooms

Room	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Finishing and polishing laboratory	**0.9**	**1.8**	**2.3**	**1.5**	**3.7**	**3.2**	**2.9**	**1.8**	**2.1**	**2.6**
Ceramics laboratory	**0.7**	**0.2**	**0.3**	**0.2**	**1.7**	**0.3**	**0.2**	**0.2**	**0.6**	**0.4**
Laboratory of fixed prostheses	**0.7**	**1.2**	**1.3**	**1.1**	**2.3**	**1.3**	**0.9**	**0.9**	**1.41**	**1.7**

One may therefore observe that the highest amount of powders is concentrated in the processing laboratory, where deflasking and sandblasting operations are also performed; the lowest value of respiratory powders is registered in the ceramics laboratory, where only veneering of the metallic frameworks with ceramic masses and adaptation of the ceramic bridges after firing are performed.

The data provided in the present investigation are much under the maximum accepted values for respiratory powders in atmospheric air, however their high toxicity level and a constant exposure, over very long time intervals, should be necessarily had in view.

Such conclusions should make the dental technicians more aware of the risks and contamination sources to which they are exposed; also, establishment of some efficient prophylactic norms in the laboratories of dental technique is a compulsory task (fig 107).

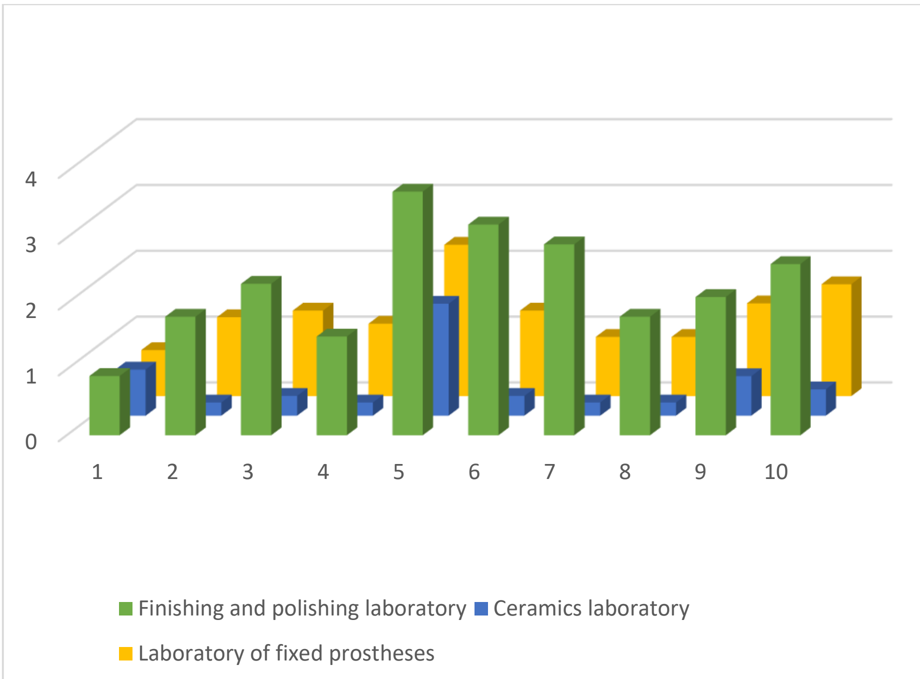


Fig. 107 Values obtained for respiratory powders in the finishing and polishing room

The average value of the dust concentration recorded in the dental lab was 2,51μg/m³, while the maximum admissible limit is 10 μg/m³.

Although all recorded values are below the maximum allowed, the high degree of toxicity and long exposure to these pollutants may cause a change in the health of practitioners.

Fine and ultra-fine particulate matter, which includes harmful bio-aerosol particles, are capable of reaching the deepest part of our lungs, being absorbed into the blood stream and having systemic effects to our health.

The danger is all the greater the longer the exposure to these dusts; associated with a high degree of toxicity, their harmful effect is even more increased.

Determination of units number forming colony per cubic meter in air, allowed to assess the microbial load in the dental laboratory at different moments of the working day (fig.108)

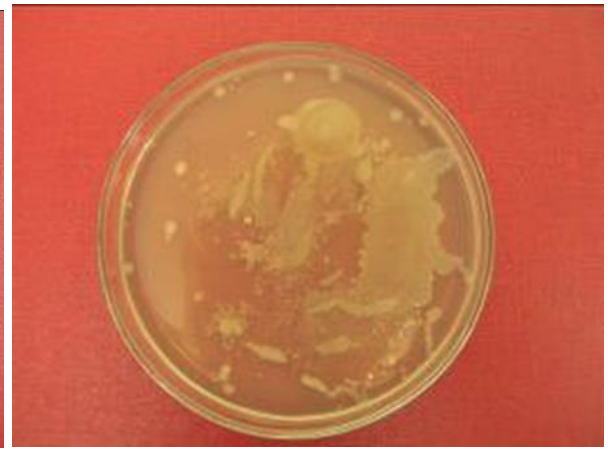
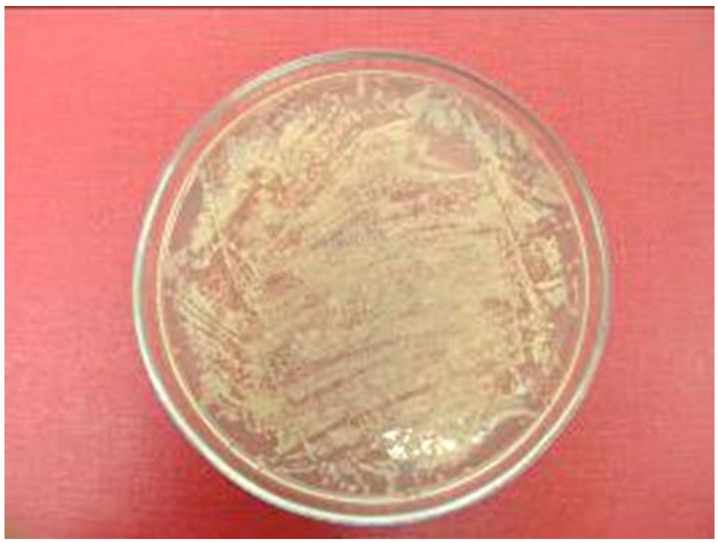




Fig.108 The Petri dishes with microbial colonies

Data obtained were statistically processed and results are expressed as mean values recorded (Table XXXVII).

Table XXXVII. CFU m³ of air in different stages of activity

CFU at the beginning of the working day (m^3 of air)	CFU during specific activities (m^3 of air)	CFU at the end of the working day (m^3 of air)
40	**873**	**86**

The highest values corresponded to intense working moments when specific technological steps are performed. Values recorded at the end of the working day, after decontamination, were lower than those obtained during the work stages, but higher than those recorded at the beginning of the day (fig.109).

This underlines the need for daily air decontamination in workspaces and use of specific measures in order to protect the medical stuff.

The resulting powders are contaminated with bacteria as a result of an inappropriate decontamination of used prostheses or instrumentation. Microbial aerosols are generated during dental treatments and may represent an important source of infection.

The level of air born bacterial pollution generated during routine activity showed that a very high level was recorded during prostheses divesting and finishing stages. Aerosols resulted from polishing procedures may cause different infection and can damage the general health status.

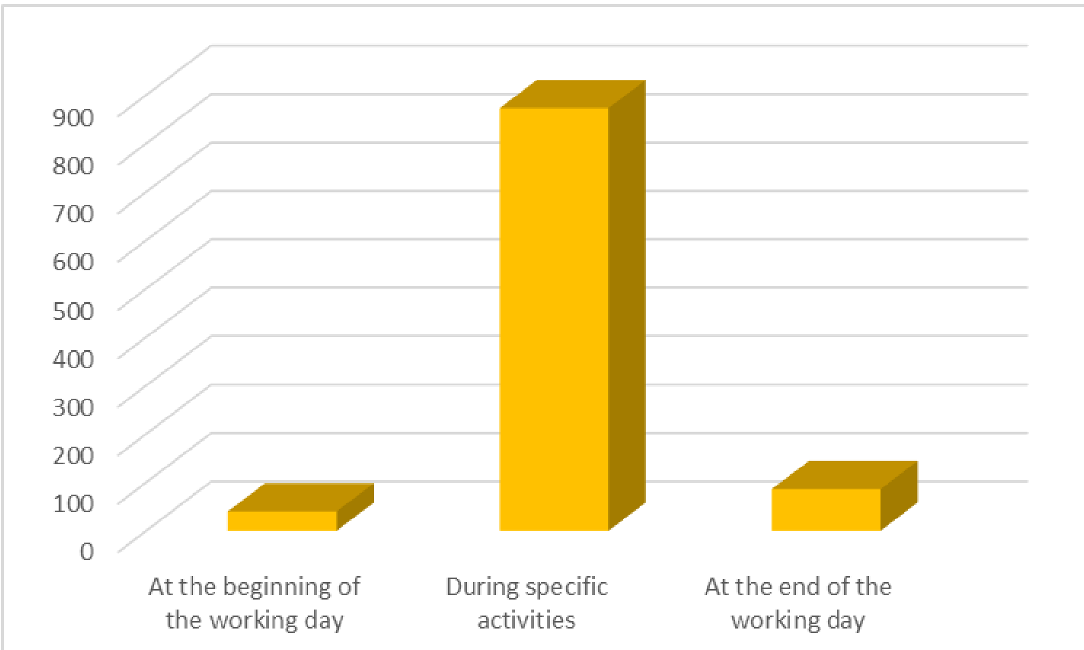


Fig. 109 Microbial load in the dental laboratory

In the literature it is specified that the maximum limit allowed in the work rooms is the value of 2500 CFU (m³of air). The highest values were obtained corresponding to periods of intense work while performing specific manoeuvres.

Values recorded at the end of the working day, after decontamination, were lower than those obtained during the work stages. This underlines the need for daily air decontamination in workspaces and use specific measures to protect personnel. It is recommended to capture dust at point where emission exhausting and discharge it externally (i.e. by using sandblasting with externally exhausting) and adequate air refreshment (40 m³/hour/person). It is also necessary to use specific protective equipment: goggles, gloves, and masks dust protection.

The existing studies results, along the current dentist activity show the necessity to introduce of a more efficient control for the medical act. In the dental praxis the rules are clear but sadly in the dental laboratory this methodology is still not enough documented. This is why the introduction of a good practical guide is vital.

Discussions

The risk of contamination during work in dental laboratories has attracted the attention of specialists, especially in recent years. If in dental offices the rules of asepsis and antisepsis are clearly established and the instrument circuit is rigorously controlled, in dental technical laboratories the risk of cross-infection still exists

Numerous studies have shown that in laboratories the transmission of microbial germs is carried out, on the one hand, through the impressions received from the office, but especially through the processing of prostheses and intermediate prosthetic parts, which have been checked or adapted in the oral cavity.

All the prosthetic devices that were not properly disinfected, after finishing and processing, contaminate the air and surfaces in the laboratory with extremely pathogenic germs. Besides theimpressions, there are a multitude of prosthetic parts that come from the dental laboratory in the office, where they are checked in the patient's oral cavity, after which they return to the laboratory for the next steps of the algorithm. So, every piece that goes from the office to the dental technician and from the laboratory to the patient must be properly disinfected.

Disinfecting products must not affect the accuracy of the prosthetic parts in any way. The most used products for decontamination ar edetergents, oxides, halogens and halogenated substances, alcohols, aldehydes, acids, phenols and derivatives, heavy metals and derivatives.

Substances used to decontaminate wax patterns must not be toxic, not affect the accuracy of the part and not have an unpleasant taste or smell. For example, products based on alcohol or sodium hypochlorite will deform the wax.

Shade guides can be can be disinfected with alcohol and for temporary acrylate bridges, hydrogen peroxide (10%-30%) and sodium hypochlorite should be avoided (0.05%), which have a bleaching effect on the resin and change the color of the prosthesis.

Crowns and bridges, after intraoral verification, must undergo a pre-disinfection stage with ultrasound. Then it is washed and applied in the decontamination solutions. Bridges with metallic framework can discolor due to corrosion under the action of hydrogen peroxide or sodium hypochlorite.

There are numerous studies that analyse the microbial air in dental offices and the contamination risk due to trespassing strictly prophylactic rules. Risk of infection depends on the minimum infective dose of any given organism, as well as the virulence (Williams DW et al., 2011).

The instruments in the laboratory must be properly disinfected before each use. In a study evaluating microbial counts of polishing pumice in a dental production laboratory there were reported abnormally high counts of pathogenic organisms.

Recommendations from many sources are to use sterilized pumice for each patient, cleanse pumice pans with a disinfectant between patients and autoclave pumice wheels between patients. The wax may be more difficult to control as it's not possible to use new blocks for each patient, and alternative methods of disinfection must be investigated. Considering that dentists have been aware of possible cross contamination for over 50 years, and that many safety precautions have been documented, it was alarming for the researchers to notice that in the dental laboratories of a large teaching hospital, there was no means of disinfection of this machinery and material (SykesI et al, 2019).

These bacteria were identified on patient dentures, pumice samples and scrub jackets. However, knowing that cross-contamination inevitably occurs in many dental laboratories, it is critical for the clinician to be aware of and follow proper protocols for maintaining an aseptic and/or sterile surgical field to ensure minimal post-operative complications (Ganesh S et al., 2013; Raiyani CM et al., 2015; Boyce R et al., 2008; Salvia AC et al., 2013).

The use of effective infection control procedures in the dental office and the dental laboratory will prevent cross-contamination that may extend to dentists, dental office staff, dental technicians, and patients (Ajantha H et al., 2011; Nimonkar SV et al, 2019) Successful practice of infection control depends on the ability to understand the need for this dynamic concept with the proper implication of method and knowledge (Ezzat A et al., 2018; Agostinho AM et al., 2004). Infection control measures such as the use of barriers during polishing, the disinfection of dentures before being sent to the laboratory and upon return to the dental clinic, the disposal or sterilization of the cone after each use, as well as the addition of disinfectants to pumice, and unit doses of pumice should be adopted with the objective of reducing the risk of cross infection (Agostinho AM et al., 2004).

In addition to the disinfection of prosthetic devices, instruments and surfaces in the dental laboratory, a series of air sterilization measures were proposed, which took on a special scope during the pandemic period. A procedure proposed for this purpose is nebulization, i.e. projecting some substances into the work room (Harrel et al., 2002).

Vaporized hydrogen peroxide as a disinfectant mist or Oxivir exce liquid disinfectant, which is a combination of hydrogen peroxide and silver ions with bactericidal, virucidal and fungicidal properties that can be used in a wide range of applications. According to the World Health Organization, it is effective against the SARS CoV-2 Coronavirus and is widely recognized as the most environmentally friendly disinfectant in the world, which has no harmful and toxic effects and is safe for humans, animals and the environment. Disinfection is it does through the Sanifog system, where the mixture of hydrogen peroxide and silver ions is dispersed with the help of dry steam (Izzettiet al, 2020, Meng et al., 2020).

Ozone is a highly reactive compound and as such is produced at the point of use by passing air through a powerful energy source such as UV light. For an ozone treatment, the room must be humidified before ozone generation and ventilated after the treatment. This type of treatment usually takes 30-90 minutes from start to finish.

Ionization involves circulating air over ionizing tubes to create charged ions that naturally seek out and neutralize charged microorganisms in the air. Ionization disinfection can be achieved by releasing a controlled amount of positive and negative ions. Some commercial facilities produce a continuous supply of ionized radicals to constantly maintain a clean environment (Virdi et al., 2021)

Another method of sterilizing the working rooms in dental labs is the use of ultraviolet (UV) light. In order to kill airborne microorganisms, the UV radiation produced by the lamps penetrates the cell membrane, penetrates the cell contents and destroys the cellular DNA, causing damage that prevents the activity of the bacteria and its ability to reproduce, no longer a threat to the human body.

The rays therefore affect the biological material, without producing chemical reactions, only by means of high power energy. Inactive microorganisms are not removed from the environment in which they are found, but they are no longer harmful. Also, UV radiation does not change the particles or chemical substances in the environment, be they organic or inorganic and the effect is disinfectant, and at high doses, sterilizing (Kitagawa et al., 2021, Gujjari et al., 2011)

The results of our research emphasize the importance of knowing the amount of the respiratory powders and other emissions present in the dental laboratory; also our conclusions can be useful for the elaboration of a practical guide of prophylactic measures to be taken.

Conclusions

Devices realized the dental laboratory are essentially inert materials which have been in contact with the patient's mouth, saliva, and possibly blood. Appliances leaving the laboratory are then returned to the clinician to be tried or adapted into the oral cavity. Relatively little attention has been paid to infection control policy within dental laboratories, due to lack of appropriate training, and lack of relevant research.

Durind the technological steps, the dental technicians are not just exposed to chemical hazards, but also to dust particles of various compositions and sizes. Research has shown that the dust from the types of materials that are used in dental technology are harmful to the laboratory team, not because of the high concentration, but due to the long exposure time and microbial contamination of these powders.

There must be a rigorous control of the disinfection of dental impressions, prosthetic devices, work surfaces, but also of the air in dental technology laboratories to prevent cross infection in dental laboratories.

All these studies are desirable, in order to identify any potentially hazardous procedures, and to make an assessment of risk for these procedures.

3. RESEARCH ON MICROBIAL CONTAMINATION OF PROSTHESES AFTER FINISHING AND POLISHING

Introduction

Another important source of contamination in the dental laboratory, overlooked by dental technicians, is represented by the wheels and pumices used in the processing of the prosthetic devices.

The risk of contamination of prostheses in the dental laboratory is an aspect that must be further analyzed and regulated in order to ensure and maintain a healthy oral function and environment.. The dentures of even healthy individuals must be considered as possible sources of pathogenic microorganisms. Regular denture maintenance and decontamination should be done to prevent and control microbial contamination of removable dental prosthesis. (Nair VV et al., 2016)

From our present research results that 75% of technicians change this type of instruments once a week, possibly due to the need to spare as many materials as possible, though the standard procedures for infection control in the labs provide a daily change.

This is performed by only 9.3% of all technicians and, depending on the length of service, we obtained statistically significant differences ($p=0.005$), only 21.1% of those having a length of service within one year declare this aspect and, unfortunately, no technician having the length of service between 1 and 5 years declares this (Kartika UK et al., 2015; Lima JF et al., 2016) In a similar survey carried out in Jordan, it has been noticed that 85% of technicians very rarely change the dental burs

Materials and method

To trace the contamination sources from the technical laboratory, we assessed the microbial load of intermediate prosthetic devices prior to checking and adapting them in the oral cavity. We used non-sterile prosthesis, and sterilized ones using current disinfectants.

The prosthetic parts used in this study were especially made for this study according to the classic production algorithm, Donciu V. David D. Patrascu I Serb H. (1994), using thermopolymerized acryl Prothyl Hot (Zhermack SpA). The processing procedure was carried out using classic acryl burs mounted on a 30.000 rpm Marathon N3 hand grinder and brushes, pumices and slurries used for polising, mounted on a horizontal motor (40.000 rpm). We used Abraso- Starglanz (Bredent) polishing paste. We analyzed four maxillary complete dentures and a polishing brush in order to asses the microbiologic contamination degree.

The samples were coded and analyzed as follows:

- P1 – non-sterile dentures polished using brushes and polishing paste that had been used in prior processing
- P2 – non-sterile dentures finished using burs had been used in prior processing
-P3 – sterile dentures (decontaminated with a Pursept 0.15 g/l solution) finished using burs that had been in prior processing
-P4 – sterile dentures (sterilized using a Pursept 0.15 g/l solution) finished and polished with burs, brushes and polishing paste, that had not been used in prior processing
-P5 – burs and polishing brush that had been used for prior processing
-The control was represented by sterile and non-sterile dentures analyzed before they were processed in the dental laboratory.

The contamination degree assessment was achieved by the method of growing microorganisms on Petri dishes, Simona Dunca, Octavita Ailiesei, Erica Nimitan, Stefan Marius, (2004), using nutritive agar (Merck, Germany).

The inoculum was obtained by repeatedly washing the prosthesis with 5 ml of sterile distilled water.

For the samples processed with brushes and polishing paste used prior in other processing activities we made decimal dilutions (10-1 - 10-3), that were later used for insemination. For inoculum we used a volume of 100 μl inoculum / Petri dish, and in the brushes case we conducted the insemination both by washing it and by imprinting it in the agar. The incubation (24 hours at 37° C) was followed by a quantities assessment of the microbial load and all determinations were carried out in triplicate.

Results

The experimental model that was used clearly demonstrates these premises. We underwent microbiological investigations both non-sterile and sterilized (using current disinfectants) dentures. In order to asses the microbiological contamination degree inside the dental laboratory, the dentures were processed using both new and used brushes and polishing paste.

The microbiological analysis of the non-sterile prosthesis (fig.110) showed that the processing conducted with instruments and paste that were used before in other dentures induces a considerable increase of the microbiological load (fig.111).

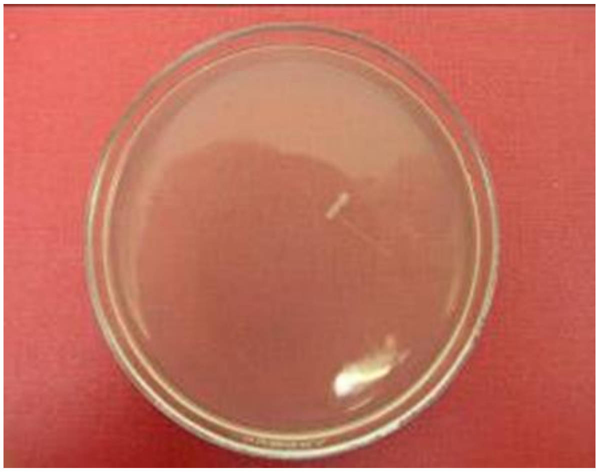


Fig.110 Microbial load of sample P1 before processing (dilution 10^{-3})

Fig.111 Microbial load of sample P1 after processing with brushes and polishing paste (dilution 10^{-3})

A lower contamination level was established for the non-sterile dentures (fig. 112) that were processed with burs that were used prior for other dentures (fig.113).

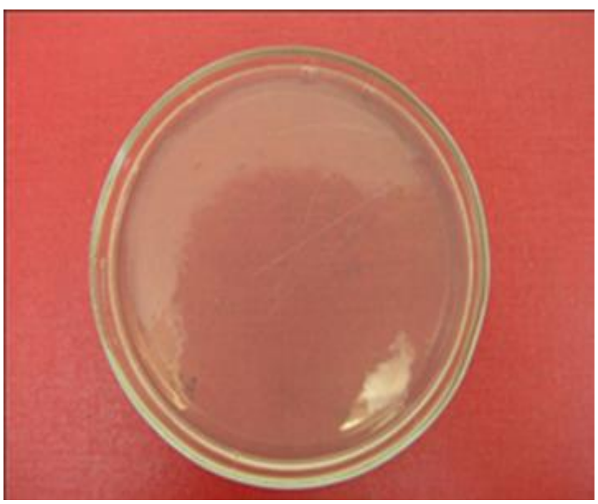


Fig. 112 Microbial load of sample P2 before processing (dilution 10^{-3})

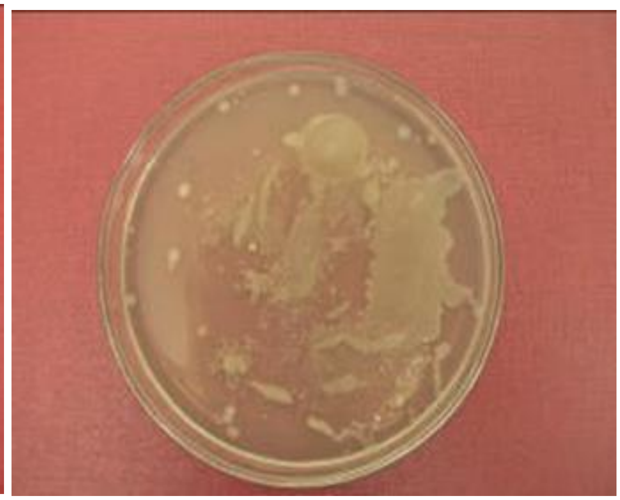


Fig.113 Microbial load of sample P2 after processing (dilution 10^{-3})

The tests show that the finishing and polishing tool has a high microbial load and if it is not sterilized it can contaminate the prosthetic constructions (fig.114, fig.115) and the staff from dental laboratory and dental offices.

Fig. 114 Microbial load of sample P5

Fig. 115 Microbial load of sample P5 (dilution 10^{-3})

The existence of two contamination sources for the dentures through the processing algorithm is also supported by the result of the analyses made on dentures sterilized with Pursept 0.15 g/l. The sterilization was carried out to remove the initial microbial load of the dentures in order to better highlight the potential contamination sources from the dental laboratory Our results confirm initial observations according to witch processing dentures with wised brushes and paste (fig.116), induce a massive contamination (fig.117).

Fig.116 Microbial load of sample P43after processing (dilution 10^{-3})

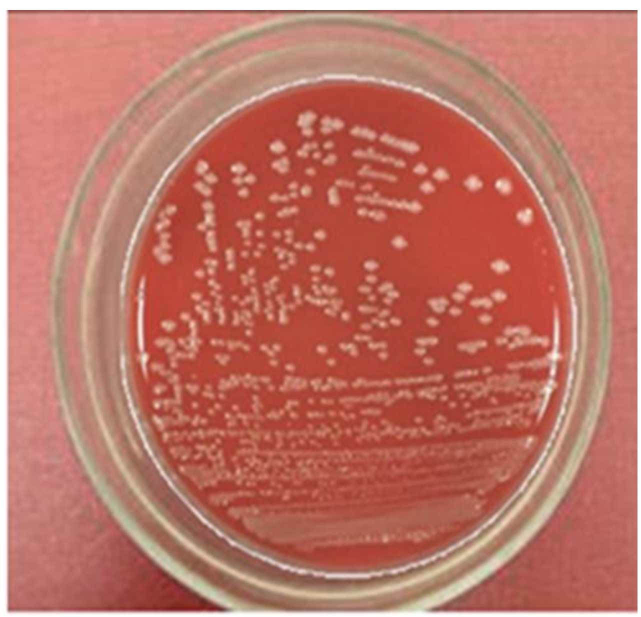


Fig.117 Microbial load of sample P3 after processing (dilution 10^{-3})

Also the test carried out in the Microbiologic Laboratory confirmed the fact that sterile dentures (fig.118) can be contaminated not only by processing them but also by simply handling them during processing (fig.119).

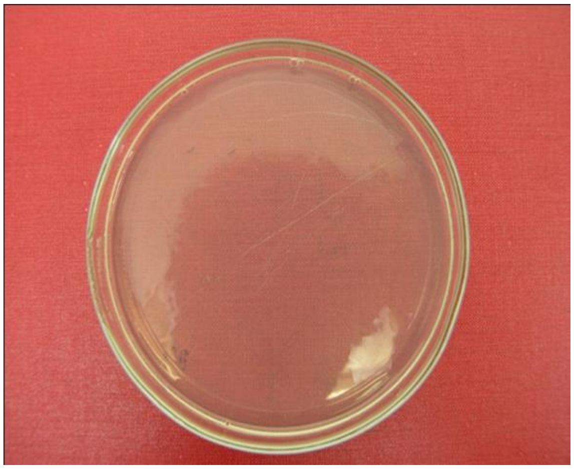


Fig.118 Microbial load of sample P4 before processing (dilution 10^{-3})

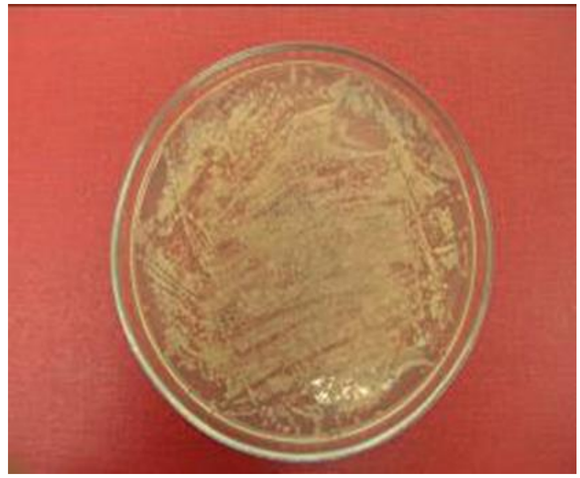


Fig.119 - Microbial load of sample P4 after processing (dilution 10-3)

Discussions

The results obtained in the present study come to complete existing studies (Vázquez-Rodríguez et al., 2018, Moodley et al., 2020, Latib et al., 2018) which have shown that in dental laboratories the transition of contaminant microorganisms is carried out by the prosthetic devices received from dental offices, but more importantly by processing these dentures that were checked and adapted in the oral cavities of patients.

Studies in the field have shown the instruments and pastes used for polishing dentures are the most important source of contamination toward the dental office but also toward the dental laboratory (Ajithan et al., 2021, Harel et al., 2004 Tellier et al., 2019).

The concern for eliminating the risk of cross-infection in the dental laboratory has been around for many years. Jagger et al, published a study about attitudes to cross-infection control of dental laboratories in the U.K. They found that only 49% of the respondents had a cross-infection policy and of these, 61% used no disinfectant in the pumice and 93% did not disinfect the polishing instruments. The need of changing this panorama has led to publications on the possibility of transmission of microorganisms between patients and professionals who, directly or indirectly, handle dental material in both the clinic and the laboratory Transmission of diseases during treatment between patients and dentists, auxiliary personnel and dental laboratory technicians can occur if preventive measures are not taken. The risk of cross-contamination in dental clinics as well as transmission of microorganisms in prosthetic laboratories has been reported in various studies (Powel et al., 1990). More than 60% of the prostheses delivered to clinics from laboratories are contaminated with pathogenic microorganisms, i.e., streptococci, lactobacilli, diphtheroids originating in the oral cavity of other patients. In prosthetic laboratories, lathes and pumice, usually used for polishing procedures and finishing of prostheses have been described as the greatest sources of contamination with levels of contamination reported of 1.4-8.0 x 105 colony forming units in pumice pans (Jagger et al., 1995).

During the polishing process, contaminated aerosols particles remain in air for a long time causing risk for dental personnel and patients. Inhalation of these aerosols is hazardous for immune – compromised, endocarditis and respiratory disease patients (Jafari et al., 2006, Sharma et al., 2016).

The dentures contaminated during polishing, may transfer organisms to the mouth and pharynx of patients and cause gastrointestinal diseases (.Savitha et al., 2015).

A lot of studies reported increased cases of pneumonia in technicians exposed to lathe aerosols working in dental laboratories and dental techniciens diagnosed with Mycoplasma pneumonia (Sousa et al., 2009, Jafari et al., 2011, Williams et al., 2011).

Kahn et al. reported cross-contamination during polishing in an experiment which simulated routine polishing of complete dentures without using any disinfection measures before the procedure or withthe addition of disinfectant to the pumice (Kahn et al., 1992)

When prosthesis is polished with pumice, contaminated aerosol particles of microorganisms such as Gram negative bacteria and fungi, are spread all around the laboratory. This could be a major source for different oral and non-oral infections. Several studies have reported isolation of Gram negative bacteria like Pseudomonas, Moraxella and Acinetobacter from pumice which can be transferred to patients and dental laboratory staff by contaminated aerosols, and cause ocular and respiratory infection especially in persons with chronic respiratory disorders (Al-Dwar, 2007) The entry of Gram negative bacteria such as Escherichia coli, Enterobacter and Klebsiella into the blood of patients can cause a fatal infection especially Gram negative septicemia in debilitated patients.Isolation of Gram negative bacteria in the current study is similar to that obtained by other studies (de Resende et al., 2006)

New studies have been conducted on viral infection transmission especially HBV and HIV in dental laboratories and suggest that all healthcare workers working in dental laboratories should be vaccinated against hepatitis B virus (Lewis, 1995)

Pacient communication and coordination between the dental laboratory and dental clinic will confirm that appropriate cleaning and disinfection practices are achieved either in the dental office or laboratory so that disinfection is secured.18 In recent years, there have been rising concerns about the disinfection of dental impressions. This is attributed to the growing awareness of viral diseases including

Viral Hepatitis B and C (HBV and HCV), Human Immuno Deficiency Virus (HIV) and Severe Acute Respiratory Syndrome (SARS) (Bhat, et al., 2007)

So, it is essential that all dental laboratory technicians must have a fundamental knowledge and understanding of infection transmission through the dental labs and how to avoid the transmission of infectious agents from dental impressions. Furthermore, they must be properly evaluated for the exposure risk they face from blood-borne pathogens Campanha et al. 2004).

There is a consensus that the prostheses are a major obstacle in the prevention of cross-contamination (McCarthy et al., 1999, Molinari et al., 1991, Pavarina et al., 2003)

In this study, we noticed that most of professionals did not disinfect prostheses arriving at the laboratory. Therefore, the handling of these prostheses may spread microorganisms to the environment thus contaminating other materials, equipment or technicians (Canpanha et al., 2004) It has been advocated that pumice used for finishing/polishing procedures consists of a major reservoir for bacterial contaminants in the prosthodontic laboratory. Denture-base resin may be contaminated by harmful microorganisms on both external and internal surfaces, due to its porous nature.

Polishing the prostheses without replacing pumice or previously disinfecting the ragwheel can lead to contamination of new prostheses by pathogenic microorganisms (Canpanfha et al., 2004).

According to the American Dental Association. Council on Scientific Affairs and ADA Council on Dental Practice regulations regardind infection control recommendations for the dental office and the dental laboratory, polishing of prosthetic appliances should be accomplished in the aseptic way to avoid cross-contamination. Therefore, the ragwheel should be thoroughly washed and autoclaved after each polishing procedure, and brushes or other polishing instruments should also be properly disinfected.

Moreover, a disinfectant solution (sodium hypochlorite 1:20) should be added to pumice, which would be used for polishing only one prosthesis and discarded afterwards. For that reason, ideal aseptic polishing would be carried out by using a sterile ragwheel, as well as adding disinfectant to pumice and discarding it after use16. Unfortunately, such procedures are time-consuming, costly and, in many situations, impracticable to most laboratory.

The statistical studies we carried out demonstrated that only 63% of technicians decontaminate all the prosthetic devices coming from the dentist, impressions occupying the first place as contamination vectors in a percentage of 47.2%

Our study highlighted the main sources of contamination and materialized, through the research carried out, the presence of microbial flora on the processed devices and also underlined the importance of respecting the methods of prevention of cross infection in the dental laboratory. 75% o dental technicians declared, regarding the interval for changing the denture pumice saying that they do this every week, 5.6% daily and only 9.3% after each use; Regarding the costs that the preventive measures assume, 31.5% of technicians consider the application of all prevention methods as a supplementary financial effort (Diaconu er al., 2012).

The use of effective infection control procedures in the dental office and the dental laboratory will prevent cross-contamination that may extend to dentists, dental office staff, dental technicians, and patients. Successful practice of infection control depends on the ability to understand the need for this dynamic concept with the proper implication of method and knowledge (Sawabi et al., 2013)

A study of Al-Aali et al, in 2021, and most practitioners did not have enough knowledge on proper guidelines and policies and it is mandatory to establish formal and obligatory infection control courses and guidelines for dentists and technicians, to minimize occupational risks.

Conclusions

Knowing the sources of contamination in dental laboratories allows a correct assessment of the risk of cross-infection and of the consequences on patients, dentists and dental technicians.

The technological steps for complete dentures realization, using conventional methods, involve a large number of technological stages and, implicitly, numerous intermediate prosthetic devices.

Not only dental impressions are a source of contamination but also working models, temporary prostheses, diagnostic wax-up, shade guides, wax rims, wax patterns, face bows, custom trays, as well as finishing and polishing tools.

Improperly disinfected prosthetic elements release contaminated dust into the work environment, which increases the risk of cross-infection.

Polishing of dental prostheses can cause a dangerous cycle of cross-contamination involving dentists, laboratory technicians, patients and auxiliary personnel.

In prosthetic laboratories, lathes and pumice, usually used for polishing procedures and finishing of prostheses have been described as the most importante sources of contamination

Although there have been concerns in this field for many years, there is a lack of concretization of results as a direction of practical application, so that the achievement of a guide of unitary measures to be observed in all dental work units is an extremely necessary and unique measure.

Anyhow, cross-contamination probability between the clinical setting and the dental technician seems to be greater than contamination risks between dentist and patients or from one patient to another. In fact, and despite the lack of contact with patients, dental technicians have been reported to experience significantly higher exposure to hepatitis B virus than a comparable population (2.7% vs. 0.76).

The conclusions drawn from this study are useful for the elaboration of a practical guide of effective prophylactic measures in order to establish strict rules of asepsis and antisepsis within the clinical-technological algorithm for making dentures.

SECTION C
FUTURE EVOLUTION AND DEVELOPMENT PLANS ON SCIENTIFIC AND ACADEMIC CAREER

The field of dental technology is extreme lybidder for scientific research and at the same time extremely challenging, as a result of the unprecedented technological evolution in recent years in the field of dental materials and in the methods of dentla prostheses realization. New technologies do not replace conventional ones, but only complement them; therefore it is necessary to permanently analyze and compare the characteristics of existing materials and technologies with those recently proposed by the manufacturing companies.

In order to choose an optimal treatment solution, the dental team currently has a very wide range of variants, which makes the choice extremely difficult, because the information in this area is not always complete

The role of scientific research is to make available to practitioners precisely these data, necessary to take correct therapeutic decision, depending on the clinical situation.

My experience in the discipline Technology of Dental Prosthesis has shown me that the research activity cannot be separated from the didactic one and the studies we have carried out have allowed us to be constantly up to date with all the news in the field of dental technology and to be able to optimize the curricula according to the evolution of technologies and dental materials and to implement new therapeutic protocols in practice.

The permanent goal was to train specialists connected to the latest technologies able to apply and transfer in the current activity the acquired information.

In this sense, there must be a permanent correlation between the research activity and the didactic one, and this interdependence must be concretized in several directions, which aim to optimize existing curricula, by introducing new disciplines in accordance with the evolution of dental technologies and materials, implementing new technologies in practical activity, promoting the results of scientific research, attracting students in scientific research and initiating them in research methodologies.

By cultivating the appetite for research of students and young doctors, we will encourage their desire to continue their training through master's and doctoral programs and to participate to various research projects.

The materials for prosthetic constructions and, implicitly, the technologies, are in a continuous evolution, that is why continuous research is necessary, in order to know the advantages and disadvantages of the new systems, in order to choose an optimal and individualized therapeutic solution, depending on each clinical case.

1. FUTURE DIRECTIONS IN RESEARCH ACTIVITY

The major path of my future academic research will concern directions and areas that are already in progress, involving activities that made the fundamental of my last year preoccupations.

At the same time, I propose to follow new research directions, in order to optimize the existing research base and to attract new funds and equipment in order to develop it.

Interdisciplinary and trans-disciplinary collaborations as well as partnerships with other universities in the country and abroad and with prestigious research centers will obtain valuable scientific results, increasing the academic performance of the “Grigore T. Popa” University of Medicine and Pharmacy of Iasi

1.1. Silver nanoparticles effect on the characteristics of dental acrylic resins

a. EXPERIMENTAL STUDIES

Studies on the long-term behavior of of acrylic resins with Nanosilver Addition

In this research area I intend to continue the studies focused on experimental research in the field of acrylic resins and removable prostheses, in collaboration with the specialists from Faculty of Medical Bioengineering “Grigore T. Popa” University of Medicine and Pharmacy of Iasi, Faculty of Materials Science and Engineering, “Gh. Asachi” Technical University and “Petru Poni” Institute of Macromolecular Chemistry of Iasi.

The research carried out so far has allowed to draw pertinent conclusions regarding the biomechanical behavior of acrylic resins with Nanosilver addition, allowing the indication of an optimal concentration and size of nanoparticles, which do not alter the parameters of these materials.

However, additional studies are needed to analyze the characteristics over time of mobile acrylic prostheses made of AgNPs enriched resins.

Polymers and polymeric composites, tend to degrade and lose their mechanical properties due to the influence of the biological environment and temperature variations into the oral cavity

(Ziąbka et al., 2021). Therefore, thorough investigations should ensure their functionality over a certain period of time (). Recently, many studies have described the bactericidal and fungal effects of silver nanoparticles (Ziąbka et al., 2019). However, there are few studies devoted to the influence of silver nanoparticles on the mechanical properties of composites over a long research period (Ranganath et al., 2018).

A number of studies on the long-term behavior of resins with nanosilver show that the mechanical properties of resins - microstructural, surface and mechanical properties, are not affected by the oral environment even after a few years, and can improve physical properties of these dental materials (Machado-Santos et al., 2020 , Karabela et al. 2011).

Other studies have concluded that acrylic resins, it has a long-standing drawback that is lack of strength particularly under fatigue failure inside the mouth and also shows low abrasion resistance and microbial adhesion onto PMMA to long-term complete dentures wearers (Fouda et al., 2019), (Madhu et al., 2021).

Therefore, some studies are still ongoing in order to solve these problems and improve acrylic polymers properties for artificial dentures (Wang et al.2015).

Recently, much attention has been directed toward the incorporation of inorganic nanoparticles into PMMA to improve its properties and the results showed that desired mechanical property enhancement can be achieved in those composites with small amounts of nanoparticles (Nam et al., 2102, Li et al., 2016)

The aim of these in vitro researches is to evaluate long term aspects regarding silver nanoparticles incorporation, such as antimicrobial potential, mechanical properties and cytotoxicity. We also emphasize the need for more studies to determine the optimal concentration of silver nanoparticle and it's release over time.

Studies on microbial adhesion to acrylic denture base resins silver nanoparticles enriched

Complete dentures, most realized of acrylic resin, allow microbial colonization, on the one hand as a result of their inner surface roughness and microporosity and on the other hand to poor oral hygiene (Song et al., 2019). Many types of oral bacteria (Streptococcus mutans, Streptococcus oralis, Streptococcus gordonii, and Actinomyces naeslundii) have been shown to contribute to the initial attachment and mature development of biofilms on acrylic denture surfaces (Philip et al., 2018).

Denture stomatitis still represents a challenge for dentistry, and research on the prevention and treatment of these diseases is a constant concern for specialists (Corrêa et al., 2015). Although significant numbers of study that focus on developing antimicrobial agents to overcome this problem exist, most of these attempts failed to achieve desired outcomes due to the rapid degradation and fast release of antibacterial agents causing low efficiency and safety concerns (Cao et al., 2017}

Antimicrobial nanoparticles are promising because of several advantages such as ultra-small sizes, large surface-area-to-mass ratio and special physical and chemical properties, but the antimicrobial mechanism of AgNPs even though it has been so intensely studied it remains unclear.

Accordingly, AgNPs have been satisfactorily incorporated into polymers used as tissue conditioners and as denture base (Suganya et al., 2014). Some authors attribute the antimicrobial effectiveness to the silver ions release (Jin et al., 2017) and others to the direct contact between the material and the microorganisms (Liu et al., 2104).

The research we conducted on the effect of AgNPs on acrylic resins used for removable dentures realization, in accordance with the results of other studies (Ghaffari et al., 2015; Mahross et al., 2015) allowed to establish an optimal concentration and dimensions of nanoparticles that do not affect the mechanical properties of dental prostheses.

The studies that we intend to carry out further aim to analyze the antibacterial effect of the silver nanoparticles introduced in the acrylic resins used to removable dentures realization.

AgNPs used in dental materials are incorporated through distinct ways, depending on the type of material. For composite resin and adhesive systems, the most common technique is adding a monomer, usually 2-(tert-butylamino) ethyl methacrylate, in order to improve Ag salt solubility in the resin solution (Cheng et al., 2012; Meloet al., 2013).

Another difference is related to the form of AgNP obtainment. In some studies the particles are commercially available, so they are obtained directly from the producer (Kasaee et al., 2008; Diaconu et al., 2016).

In others, AgNPs are prepared by reduction of AgNO3, with NaBO4 (Flores et al., 2010) polyvinylpyrrolidone (Nam, 2011), sodium citrate (Monteiro et al., 2012), or gallic acid (Espinosa-Cristóbal et al., 2009)

The research will follow the comparative efficiency of this process of optimization of composite materials, in the desire to establish which method provides the highest antimicrobial and antifungal potential.

In vitro studies on the cytocompatibility of dentures bacrylic resins AgNPS modified

AgNPs have been applied in several areas of dentistry, with the aim of avoiding or at least to decrease the microbial colonization over dental materials, increasing oral health levels and improving quality of life.

The antimicrobial potential of silver nanoparticles is indisputable and is demonstrated by numerous studies (Prażmo et al., 2016; De Souza Neto et al., 2018;) the small size of AgNPs offers them the possibility to penetrate through cell membranes more readily, resulting in higher antimicrobial activity (Park et al., 2013), which is especially important since microorganisms in biofilms are very resistant to antimicrobial agents (Corrêa et al., 2015)

Nanotechnology has evolved as a favorable tool in medical field and dentistry. Nanoparticles offer an attractive alternative to conventional antimicrobial agents. (Halkai et al., 2016). Among the precious metals, silver (Ag) is considered in the field of biological system, and medicine can be effectively used as antimicrobial agents because of their broad spectrum of activity and biocompatibility (Halkai et al., 2019).

Considering their unique physical and chemical properties, it is likely that these nanoparticles also possess unique toxicity mechanisms (Chaloupka et al., 2010).

Some in vitro studies, performed on fibroblast cell lines, on the antifungal activity of AgNPS against Candida albicans demonstrate that PMMA denture base material containing silver nanoparticles have antifungal activity and no cytotoxic effect (Kurt et al., 2017; Sabri et al., 2021).

The addition of antifungal agents on PMMA surface or into PMMA, such as nanoparticles, could be useful for the inhibition of oral specific pathogens. (Arenas-Arrocena et al., 2017)

Other studies state that AgNPS, in certain concentrations, may have toxicity, which depends on the type of nanoparticles used (synthesized in the laboratory orindustrially obtained), their size and concentration (Awasthi et al, 2015). AgNPs toxicity involves various mechanisms, in particular the production of excess reactive oxygen species (ROS). One of the possible mechanisms proposed for AgNPs toxicity, the production of excess ROS, seems to be the most important contributor for nanotoxicity or nanocytotoxicity (Gurunathan et al., 2018)

Due to the enormous uses of AgNPs in the medical and dental field, we propose that in our future studies in this direction to analyze and evaluate the use of these materials so as to avoid a potential cytotoxic effect. We also aim to determine the size and concentration that ensures optimal biocompatibility of these materials used to make removable dental prostheses.

These in vitro studies are necessary primarily to verify the results of mechanical and laboratory studies performed to date; research is also useful to analyze the long-term efficacy of modified silver nanoparticles acrylic resins, as the aim is to ensure a long-lasting antimicrobial effect in dental devices.

b. CLINICAL STUDIES

Clinical studies on the behavior over time of acrylic removable prostheses silver nanoparticles modified

Silver nanoparticles are successfully used in dental prosthetics, especially to reduce the risk of microbial colonization of revovable prostheses and to avoid inflammation of the oral mucosa, common on wearers of removable dentures.

There are many in vitro researches that analyzes the behavior of modified AgNPS acrylic resins, but there are very few clinical studies that track the performance over time of prostheses made from these materials. (Banjonga et al., 2020).

The value of laboratory investigations is usefull, and by following a strict protocol for re-evaluating these studies, the quality may be determined for such an important subject matter as the use of nanoparticles for dental treatment (Adam et al., 2021)

Recently, the importance and value of the research designs such as randomized clinical trials and synthesis research were gaining more exposure (Higgins et al., 2009)., serving as a guide to practitioners to improve treatment and care to patients.

Reported on materials used in dental medicine many studies start at the laboratory investigations and very few subsequently get involved with related clinical research. The reasons for this approach are probably related to how feasible the outcomes may be in clinical studies; long observation periods in clinical research; ethical requirements with patient-related research; exorbitant costs associated with clinical research and difficulties with implementing rigorous design principles. Laboratory investigations include or exclude the use of nanoparticles in dentistry depending on the quality of the included studies and their outcomes and subject matter may add great value to daily clinical practice if it is determined that nanoparticles may influence the oral effects of Candida Albicans (Adam et al., 2021).

Silver nanoparticles have been used in dentistry for different purposes and in different forms, for all types of materials, within different systems: composite resins and adhesive systems, acrylic resin, endodontic materials and titanium implants. Biosynthesised silver nanoparticles have been shown to be antibacterial in nature against a number of dental pathogens such as S. mutans and Lactobacilli species (Burdusel et al., 2018). Previous studies have reported on the incorporation of chemically synthesised silver nanoparticles into denture acrylic (Acosta-Torres et al., 2012). In order to prevent denture stomatitis and treat recurrent infections, the incorporation of antimicrobial agents into denture base resin and resilient liners have also been reported (Lima et al., 2016; Ramos et al., 2017)

Modification of denture bases and denture liners with silver nanoparticles present a unique opportunity to manage denture stomatitis. It is advantageous as the modified dentures are in contact with the tissue, thereby preventing re-infection. Sustained release of a drug from the denture base could further prevent the development of a biofilm and the colonisation by Candida albicans. Nanomedicine refers to the use of nanotechnology in the diagnosis of disease, drug design and delivery, and implants (Gendreau et al., 2011).

The purpose of these future studies is to evaluate in timp clinical behaviour of removable acrylic dentures AgNPs, to evaluate the success rate and treatment outcome of these protheses, to monitor for possible damage to the oral mucosa and to determine the antimicrobial efficacy of silver nanoparticles included in acrylic dentures and in different denture liners.

We also aim to develop a protocol to guide practitioners in the unitary implementation of these clinical trials using ethical principles, which want to cover a wide range of analysis and gather as much information as possible, in order to draw relevant conclusions of practical importance.

Given that there are few long-term clinical studies on the behavior of AgNPS modified full dentures, I believe that our research could be a valuable contribution in this scientific area.

1.2. Comparative studies on digital and conventional technologies for complete dentures realization

In dental medicine, several digital workflows for production processing have already been integrated into treatment protocols, especially in the rapidly growing branch of IT-power CAD/CAM systems and rapid prototyping (RP) New possibilities have opened up for automated processing using artificial intelligence (AI) and machine learning (ML). Moreover, augmented and virtual reality (AR/VR) is the technological basis for the superimposition of diverse imaging files creating virtual dental patients and non-invasive simulations comparing different outcomes prior to any clinical intervention (Joda et al., 2020).

Since the conventional method of fabricating CD was established more than 80 years ago, the continuing goal was to improve all the drawbacks associated with the process of fabrication, and enhancements of the properties of PMMA material (Harini et al., 2020).

From a technological point of view, full denture is easy to make (the technique being simple and the laboratory does not require high-performance equipment, but a number of problems arise when adapting it, due to important changes in the elements of the stomatognathic system and the installation of major imbalances oof the oral cavity.

The material choose for complete denture realization is very important, in order to have an optimal adaptation; therefore, implicitly, the appropriate technology must be known in detail, in order to avoid errors during the clinical and technological steps. The continuous evolution in the field of dental materials has led to the production of non-acrylic resins, clearly superior to classical materials (Diaconu-Popa et al., 2020). In certain clinical situations, the acrylic denture, in its conventional version, does not meet all the requirements or fails to properly restore the functions, due to certain features of the prosthetic field. Therefore, it is necessary to know all the possibilities of treating complete edentulism, in order to be able to choose the optimal therapeutic option (Tatarciuc et al., 2020; Al-Fouzan AF et al., 2017)).

Recently, digital technologies for fabricating complete dentures have become more well-known and commercially available, and the methods and materials are more and more efficient, allowing to obtain complete dentures according to the highest requirements. These procedures offers significant advantages to the dental practitioner, dental technician and also to the patients. CAD/CAM-substractiev technology have three important steps (Burde et al., 2019): data acquisition, by using intraoral scanners or by scanning a stone model from a conventional impression, designing virtual devices in order to generate data for the future restorations, and computerized realization of the full denture, using state-of-the-art materials.

A number of researches point out that the resins used in computerized technologies for full dentures are industrially produced, and therefore have a high resistance to impact and distortion, resistance to blanching, color stability and dimensional stability. They also emphasize that prepolymerized acrylic resin are produced under high pressure and heat and polymerization shrinkage does not occur, porosity is ecreased, and the adherence of Candida albicans to the denture base is decreased. The lack of polymerization shrinkage associated with milled dentures results in a highly accurate denture fit and a better retention and also, the CAD/CAM denture base milled from poly-methyl methacrylate discs, polymerized on high temperature and pressure have been reduced the risk of residual monomer (Alghazzawi et al.,2016; Janeva et al., 2017)

Other researchers claim, there are also limitations and disadvantages of these CAD/CAM technologies, such as: incorrectly recorded intermaxillary relation, lip support and maxillary incisal edge position are challenging, difficulties in establishing the occlusal plane, the opportunity for the patient to participate during the procedure is minimal, current material and laboratory costs are still more expensive compared to the conventional techniques (Baba et al., 2016). 3D printing technologies represent another possibility of realizing complet dentures by computerized methods. Additive manufacturing technologies are essentially a method of getting devices with complex spatial geometry through additive processes. Additive manufacturing is gaining rapid potential in nearly all dental fields and it is different in comparison to the formative and subtractive manufacturing, in the additive manufacturing process the device being printed by adding the material layer by layer (Kattadiyil et al., 2015). Compared to the subtractive CAD-CAM technology for the elaboration of prosthetic appliances based on computer-controlled milling, 3D printing offers the advantage of unlimited design flexibility, the elaboration of the prosthetic device being realized in a few single steps. 3D printing has several advantages compared to conventional technology - superior accuracy, developed thanks to additive technology which, compared to subtractive techniques, allows superior reproduction of details; also, the increase of the work efficiency, being able, to elaborate, simultaneously, several prosthetic works, the reduction of the consumption of dental materials and of the working time (Goodacre et al., 2016).

The disadvantages are: the high costs of digital processing programs and printers themselves, the more limited accessibility of materials for this technology, the flawless design of the future prosthesis (Bidra et al., 2013).

In this context, our future studies will focus on the following research directions:

- Analysis on the mechanical parameters of acrylic prostheses performed by conventional methods and by computerized additive and subtractive methods
- Comparative studies between digital and convention full denture base adaptation, retention and marginal fit
- Comparative studies on dimensional accuracy of digital and conventional realized by additive and subtractive methods

In order to determine the most correct therapeutic solution it is necessary to know the characteristics, advantages a disadvantages of each technologie and material used for prosthetic restorations.

1.3. Research on the possibilities of using digital technologies in the dental laboratory

The digital technologies had a huge impact on dental workflow that led to quality improvements (more precise, effective and personalized treatments), labor cost reductions and time saving (reduced production or treatment time, shorter waiting times and higher patient satisfaction

Many laboratory prosthetic elements can be made using these digital methods - from intermediate parts - models, temporary devices, to metal, ceramic or zirconia frameworks and dental prostheses – crowns and bridges, or partial and complete dentures (Joda et al., 2017; Amin et al., 2017).

The main computerized methods used in practice today are subtractive and additive systems (Topol, 2019, Alikhasi et al., 2018).

Subtractive methods are the most common manufacturing technologies whose principle is to get the prosthetic construction by milling a block of material. As soon as the CAD unit has created the digital design, it will be exported to the CAM unit, either at the dental office or at the dental laboratory, in STL format and the machining will allow the block to be shaped according to the prosthetic element. The additive technologiescharacterize with the building of one layer at a time from a powder or liquid that is bonded by means of melting, fusing or polymerization. The methods, mostly used in prosthetic dentistry include stereolithography, selective laser sintering (SLS), selective laser melting (SLM) and Electron Beam Melting (EBM).

CAD-CAM technology for model realization involves the development of a resin device that achieves high precision, better accuracy and ensures a complete transfer of clinical information to the dental laboratory (Constantiniuc et al., 2021; Srinivasan et al., 2018).

The temporary bridge is an intermediate prosthetic element, mandatory in fixed prostheses work flow. Digital technologies allow obtaining such devices, in a very short time, even in the dental office, in the same appointment with the abutment preparation (Revilla-León et al., 2019; Steinmassl et al., 2018).

The wax patterns can be realized by subtractive or additive digital methods. Through these computerized methods can be obtained wax patterns with uniform thickness, very precise and with very good adaptation, which facilitates a faster and easier final processing of the metallic framework.

The additive and subtractive computerized methods are also used in the laboratory for the realization of the metallic framework of the conventional bridges and for the metallic framework on removable cast partial dentures (Svanborg et al., 2020); the subtractive methods are also used to obtain the framework of zirconia or all ceramic bridge.

Studies on the advantages, disadvantages and particularities of dental materials and technologies are presented in the literature, ranging from the most traditional to the most modern one. A lot of advantages have been reported over conventional methods, including low cost of materials, less complex labor and good quality of the devices. But, it has been proven that CAD/CAM methods, allowing digital impressions and allowing to do away with plaster models, wax-ups, casting and firing, are able to be faster and easier than conventional technologies (Rekow et al., 2020)

The quality of the CAD / CAM restorations is very high thanks to the precision of the measurements and the manufacturing, have a natural appearance and good mechanical resistance. Although the purchase price of such equipment remains a real investment, the gain in speed of design and manufacture allows practitioners to be able to make a profit after a certain number of restorations (Touchstone et al., 2010)

Nevertheless, the cost can just as easily be seen as a disadvantage; there are still some drawbacks concerning modern manufacturing technologies such as the high initial cost of equipment and software.

Our patients today have much differentiated needs and demands compared to previous stages and it is no longer possible to design a prosthetic treatment without considering an impeccable functional recovery. From a clinical perspective, the important aspects to be considered for prosthetic work performed by computerized techniques are long-term longevity in the oral cavity, significant reduction in working time, reasonable costs and clinical versatility.

From a technical point of view, there is still a learning time which is essential in order to master these new machines (Goss et al., 2019).

In order to implement the digital systems into the laboratory of the Clinical Base of Dental Education, a series of preliminary studies are necessary, which guide us if it is justified to purchase such equipment and materials, as well as additional training of our dental technicians.

Thus, our research will focus on a comparative analysis of the characteristics of prosthetic devices, realized by digital and conventional methods, on the analysis of the possibilities of streamlining the technological steps, as well as on the usefulness of outsourcing digital lines, in order to make all types of prostheses for private laboratories.

Other future directions for the research activity:

- Development of interdisciplinary and transdisciplinary collaboration relations
-Submission of research projects in order to optimize the existing research base and attract new funds and equipment in order to develop it
-Active participation in national and international scientific events, in order to communicate the results of our own research and increase the transparency of our activity department, in order to initiate new scientific collaborations
-Elaboration of high-performance technologies, with the possibility of their implementation in the current medical activity and optimization of the professional performances of the practitioners, for the benefit of the patients
-Developing high-performance research centers in the faculty and stimulating participation in competitions for international scientific projects and accessing European funds for research by providing concrete institutional support.

-Continuing the balanced development of the existing research infrastructure and its use in the wide interest of the research teams
-Development of collaboration between university faculties as well as inter-university cooperation, in order to emphasize the interdisciplinarity of research, an essential condition for obtaining valuable results that contribute to the scientific performance of the university
-Identify all funding opportunities, from grants to independent funding
-Extension of interdisciplinary research fields,
-Identifying promising research topics
-Implementation of the most representative results into the dental practice;
-Continuous improvement of the members of the research team;
-Making national and international partnerships.
- Organizing of a defectoscopy center to analyze the quality of all prostheses made by our technicians or prostheses made in dental private practice

2. FUTURE DIRECTIONS IN ACADEMIC ACTIVITY

2.1. Academic activities regarding students and residents

A high quality educational process is of interest to both teachers and students of our faculty. The main objectives of the teaching process are, on the one hand, the training of students at the highest professional level, according to the requirements and opportunities on the labor market, and on the other hand, the increase of their own professional performances, in order to achieve the necessary practical skills. In this sense, the aim is to ensure the materials and equipment necessary for the practical activity, to provide them with theoretical support and to stimulate interest in performance, in order to train them as valuable specialists.

The development of clinical skills requires extensive knowledge and ability. Recently, the requirement is substituted by simulated training obtained through artificial intelligence (AI) – virtual reality (VR) and augmented reality (AR). The VR is creating a simulated environment, whereas AR is a division of the same, but it augments sensory perception and replicates real environment in virtual world (Huang et al., 2018, Chander et al., 2019).

Practical skills are only part of the skills required of future doctors, but they are a very important component that should be tested, evaluated and developed. In this sense, there is the continuous concern for increasing the quality of the didactic act, with paying more attention to the practical activity (Touati et al., 2019, Joda et al., 2019).

Theoretical and practical training of graduates must be in accordance with the needs and requirements of the national and international labor market. In order to achieve this goal, my future objectives will consist in deepening the acquired knowledge and skills, permanent self-training in order to acquire new knowledge related to educational activity, acquiring skills in related fields for interdisciplinarity, developing new approaches in my own teaching activity based on teaching strategies, developing new approaches in teaching activity, based on interdisciplinary and multidisciplinary teaching strategies, improving the ways of transferring information in courses and seminars.

Future directions regarding teaching activity for students:

The future directions for optimizing the didactic process consist in:
-ensuring access to modern information sources, ensuring the support of edited teaching material and in electronic format to the profile disciplines

- coordinating student scientific activities, involving students in research teams and stimulating their active participation in student scientific events
- implementing self-assessment and assessment of students' knowledge and stimulating them to accumulate new information through individual or team projects
-initiation of collaboration programs and inter-academic exchanges with the profile faculties from the country and abroad
- orientation of the preoccupations for the reorganization of the didactic process by restructuring the content of the study programs and of the curricula, following their connection to the norms imposed by the European Community
- creating a new dimension of undergraduate and postgraduate education by developing online distance learning
- ensuring a balance between students' expectations and the educational and managerial offer of the faculty
- the introduction in the educational process of some optional or voluntary disciplines, which would allow the students to capitalize on other values, indispensable for some professionals in the domain of medicine
-facilitating students' access to recommended bibliographic materials
--stimulating students in order to continue medical education in masters, doctorates and medical skills courses
-involvement in international mobility programmes

Future directions regarding teaching activity for residents:

- providing up-to-date information within the educational process through the consultation of existing databases, websites and specialized articles
-guide and supervision regarding the medical activity of the resident dentists of Dental Prosthetics and General Dentistry, who carry out clinical internships within the discipline;
-supervising the stages of prosthetic treatment on patients with different forms of edentulousness, both by fixed prostheses (on natural teeth or on implants), andremovable prosthesis with exclusive mucosal support, mixed or over-dentures on implants;
-stimulating residents to participate in practical skills courses, adapted to the curriculum for Prosthetic Dentistry residency;
-initiation of residents in the use of digital technologies in dentistry and their involvement in the implementation of computerized systems in the current dental activity
-stimulating residents to get involved in research, within the limits of skills and level of training; the research is carried out mainly in the discipline of Dental Technology, but collaborations with other disciplines within our university, and with other universities in the country and abroad are also encouraged.

Other strategies in the teaching field I intend to focus on:

- new didactic materials meant to facilitate the acquisition of knowledge in the field (course materials, worksheets and guidance of practical works)
- implementation of modern training means
- stimulating the active involvement of students in courses and practical activities, using teaching methods focused on learning through discovery, collaboration and team learning
- involvement of students in teaching and research activities,

- diversification of evaluation techniques for students and residents and information on the evaluation criteria of their activity
- training of young doctors able to apply and transfer the acquired information
- equipping laboratories and clinical disciplines with medical equipment, materials and instruments to ensure students and residents a medical practice at European standards, in order to achieve excellence in medical training and provide the labor market of a newly connected human resource, ready to higher level
- development of an integrated computer system to record the professional evolution of students at all levels of study
- participation to courses in the fields related to Dental technology and Dental Materials
- students' active involvement in the carrying out of courses and internships;
- new post-university courses in Prosthetic area and interdisciplinary fields;
- implementation of efficient active-participatory teaching methods in order to transform the students from information receivers into co-participants to the didactic process; these learning methods will optimally train future specialists, thus determining them to have not only useful and valuable information, but also to have their own opinions, based on rational arguments, to actively participate in finding solutions and to learn to collaborate in the team.
- initiating of research projects whose results can be capitalized in order to develop bachelor's or dissertation theses.

2.2 Academic activities regarding future doctoral students

The doctoral study is the basis of academic practices and previous research on doctoral education has identified several factors that contribute to the successful completion of this research project. The research proposal is probably one of the most important parts of the application process since it will demonstrate the background knowledge of the topic, methodology and the proposed research plan.

But just as important is the guidance by the supervisor of the young researchers during the project, interdisciplinar collaboration and support, in order to succesfully finalize the thesis and disseminate the results.

My 27 years of teaching experience in the Discipline of Technolgies of Dental Prosthesis and my research activity throughout this period give me assurances that I will be able to advise PhD students in order to carry out interesting research projects, the results of which can be used in current dental practice.

The directions related to PhD candidates' activity focus on:
-selection of high-performing students, with an appetite for research, with good or excellent academic record and their stimulation to continue with doctoral studies
- support and guidance of PhD candidates in interesting research topics,
- support for the use of the most effective scientific methods necessary for conducting research and advice development of the research study protocol
-guiding doctoral students in order to achieve collaborations in the field of biomechanics, informatics, medical biostatistics, materials science and engineering
- encouraging young researchers to work in research teams
- support for writing and publishing articles in ISI-rated journals with high impact factor
- encouraging doctoral students in disseminating the results in national and international conferences and congresses

-encouraging academic mobility for PhD students
- facilitate and promote learning through active and student-centred approaches that would help PhD students to develop their research skills

Research topics specific to the field of Dental Technology can be concretized by the following aspects:

I.Digital Prosthodontic Treatments- Optimizing the adaptation and functional restoration of prosthetic devices by introducing digital analyzes into the prosthetic workflow

Fixed and removableprostheses allow the correct resumption of the dento-maxillary functions only if the occlusion ratios are perfectly restored and the mandibular-cranial relations are restored. The conventional methods of recording the interarch relationships, their transfer in the dental laboratory and especially the preservation of the recorded occlusion by mounting the models in the articulator, involve a high degree of human error. Most of the time, the technician adapts the prosthetic devices in an approximate occlusal relationship, which can generate, immediately or in the long term, serious oral adaptation problems and disorders of the temporomandibular joint.

Digital systems have improved the quality of prostheses in dentistry and found a way to standardize for therapeutic procedures. They have increased the efficiency of prosthetic treatment and given the possibility to practitioners to work with new materials, with a high level of precision.

For our further research, we propose the introduction into practice of a digital facial arch Modjaw™□ 4D Technology, aiming to analyze, comparatively, the effectiveness of conventional methods compared to digital ones. The Modjaw 4D™ system is the newest digital scanning technology in dentistry and thanks to the 4D images, the patient will be able to visualize his mastication and will have a different understanding of the treatment he needs.T he MODJAW™ 4D system is a simple and fast digital response that captures the movement of the jaw and applies it to 3D models from a laboratory scanner or directly from an intraoral scanner. The benefits

4D dentistry is a new way of practicing digital dentistry, using 3D modeling, jaw movement and dynamic occlusion of patients in order to diagnose complex dental conditions, but also to personalize treatments. In order to allow a correct diagnosis and a high-performance oral restoration, it is necessary to know the static and dynamic parameters, the occlusal guides, unilateral occlusal contact, teeth wear, the type of malocclusion or disorders of the temporomandibular joint. The software scans the dynamics of the dento-maxillary apparatus in real time, without using X-rays. The Modjaw™□ 4D system has applicability in diagnosing and performing prosthetic and orthodontic treatments (de Prado et al., 2018).

The dentist can view, track and record the movement of the jaw in real time, as well as the type of dental occlusion and the system platform can aggregate all patient data, including 3D models, 4D movements and facial CBCT scans. This recording of great accuracy allows the realization of an exact virtual replica of the patient's stomatognathic system (Sagl et al.,2021).

So, this technology simplifies complex treatments and improves the quality of dental treatments and the data are used to completely customize treatment solutions, being accessible to dental technicians, who will use CAD-CAM technology to finalize dental prosthetic elements (crowns, veneers, bridges, inlays or dentures).

Also with the help of digital systems, we aim to register the occlusion of patients with higher precision, implementing the T-Scan Novus system, which helps dentists to digitally detect and identify premature tooth contacts and the relationship between the two jaws, quickly and efficiently. The new computer technology, T-Scan has an important role in the diagnosis and treatment of diseases caused by incorrect dental occlusion, such as tooth mobility, bruxism, gingivitis and other periodontal diseases (Deepika et al., 2022, Seo et al., 2019, Resende et al., 2022).

Our studies aim to analyze the limits of these digital methods, as well as the effectiveness of introducing this system into current practice.

II. Virtual technologies in aesthetic dentistry

The aesthetic treatment is not a novelty in contemporary dentistry, but dental medicine and implicitly aesthetic therapy are in continuous evolution. Today, patients have very different needs and requests compared to the past, and prosthetics can no longer represent the segment of dental medicine today, which restores not only functional but also aesthetic The transition to aesthetic dentistry is becoming more and more, the aesthetic restoration presupposing the reconfiguration of the entire facial architecture, in order to restore the entire physiognomy of the patient. Aesthetics in dentistry includes a series of dental treatments from different areas (prosthetics, orthodontics, implantology, surgery) and a satisfactory result cannot be obtained without an interdisciplinary approach.

The conventional methods of restoring the physiognomic function are not always effective, even in the conditions where the materials for prostheses are performing and approach, both from a mechanical point of view and from the point of view of the optical parameters, the characteristics of natural teeth.

Virtual smile design is the representation of a new and healthy smile on a patient's photo using dedicated smile design software. With this software, dental treatment will never be the same because in that very first step, where the dentist discusses the plan with the patient, the patient actually has the chance to reflect on the outcome and it can be modified based on their opinion. Virtual smile designing involves photographs, intraoral scans and combines these in design software that simulates a realistic smile — a real-life smile that matches the patient's facial structure and features. Mind you: this has nothing to do with 'photoshopping' a perfect smile; it is a prelude to an actual new smile.

Patients will mostly experience the benefits of virtual design tools before the start of treatment. This period is, after all, the moment in time when they are faced with most questions about the treatment necessary and its duration. Smile simulation software helps the patient connect all the dots. The most important and tangible benefits for patients are the following:
The researchers analyzed the Digital Smile Design method and proved that it is a multi-use conceptual tool that can support diagnostic vision, improve communication, and enhance treatment predictability, by permitting careful analysis of the patient's facial and dental characteristics that may have gone unnoticed by clinical, photographic or diagnostic cast based evaluation procedures.

Digital Smile Design leads to customization of smile design by increasing the participation of patient in their own smile design which result in a more aesthetically smile (Daher et al., 2018). The patient may evaluate, provide opinion, and approve the final shape of the new smile before any treatment procedures are performed thus enhancing patients satisfaction. It leaves no scope of regret post and it also helps to evaluate and compare pre and post treatment changes. (Zanardi et al., 2016).

It not only improves communication between clinician and patient but also between interdisciplinary team members, clinician and lab technician. All team members can access this information whenever necessary to review, change, or add components during the diagnostic and treatment phases, without being available in the same place or at the same time. The lab technician also receives feedback of patients expectation related to tooth shape, arrangement, and color to enable any desired modifications (Coachman et al, 2017).

Our future research will focus on analyzing the efficiency of this system, its implementation in current practice and tracking the benefits, both for the patient and for the efficiency of the dental technician's activity.

III. Direct CAD/CAM systems for provisional and final prostheses

CAD/CAM systems have improved the prostheses quality in dentistry and found a way to standardizet he therapeutic procedures. They have increased the efficiency of prosthetic treatment and given the possibility to practitioners to work with new materials, with a high level of precision.

As part of the direct digital production protocol, all the steps will be carried out in the dental office and, ideally, in a single session. The dentist, equipped with the camera for the optical impression, CAD software, CAM device will be the only operator of the prosthetic chain, offering to the patients an effective and immediate prosthetic solution Markus et al., 2019, Touri et al, 2019).

Digitaltechnologies, additive or subtractive, will allow, by reducinng the workflow, maximum efficiency of dental treatment and maximum patient satisfaction.

Additive methods, 3D printing and LASER microfusion, were used especially for obtaining frameworks for fixed or removable prostheses, implant surgical guides and orthodontic mouthguards. Sstereolithography can be used to realize resin models from, temporary bridges or provisional removable prostheses (Revilla-León et al, 2018).

Subtractive technologies were the first digital methods also used in the creation of fixed or mobile prostheses, but they involve a very large investment and are considered very expensive.. In the pandemic period, the addressability to dental practices has decreased and there has been reluctance on the part of patients but also on the part of dentists to start or continue dental treatment. In this context, digital technologies was a real help, allowing many risks to be eliminated.

At present, digital systems have taken on a greater scope in dental practice, tending to partially or completely replace the stages of the conventional algorithm for the realization of prosthetic constructions and different materials (polymers, metals, and ceramics) and equipment are commercially available for various dental applications such as custom trays, surgical guides, temporary or definite fixed or removable dental prostheses, and orthodontic or maxillofacial appliances (Svanborg et al., 2020).

Studies on the advantages, disadvantages and particularities of dental materials and technologies are presented in the literature, ranging from the most traditional to the most modern one. A lot of advantages have been reported over conventional methods, including low cost of materials, less complex labor and good quality of the devices. But, it has been proven that

CAD/CAM methods, allowing digital impressions and allowing to do away with plaster models, wax-ups, casting and firing, are able to be faster and easier than conventional technologies (Rekow et al., 2020).

From a clinical perspective, the important aspects to be considered for prosthetic work performed by computerized techniques are long-term longevity in the oral cavity, significant reduction in working time, reasonable costs and clinical versatility. The digital technologies had a huge impact on dental workflow that led to quality improvements (more precise, effective and personalized treatments), labor cost reductions and time saving (reduced production or treatment time, shorter waitingtimes and higher patient satisfaction)

What we propose as future research directions is an analysis of the characteristics of the prosthetic constructions made by direct methods, focusing on both crown and base prostheses, as well as removable, partial or total prostheses. We want to see if the mechanical and biological parameters of the CAD/CAM prostheses allow the use of these systems for the creation of definitive prostheses or only provisional prostheses.

Also, another objective is to follow the characteristics of full dentures made by subtractive and additive technologies and to compare their clinical performances with those made by conventional methods. The treatment of total edentulousness involves a multitude of clinical and laboratory stages; therefore, the results of our research could help practitioners in implementing digital systems in their work, streamlining work flow and increasing patient satisfaction.

Digital technologies represent the future of dentistry, and as the demand for such equipment increases, new systems will appear, with a better price; in this situation, they can be purchased and used more widely, both in dental practices and in dental laboratories. This will benefit the dental team, who will be able to collaborate more effectively, even remotely, but will above all benefit the patients, who will be able to be treated more quickly and in perfect safety.

Other directions in the research field I intend to focus on:

-Optimization of the biomechanical characteristics of acrylic and non-acrylic resins used for removable dentures

-Studies regarding the use of nanoparticles in order to improve the parameters of dental materials used in fixed and removable prostheses

-Studies on perspectives of Zirconia-beased restorations (single crowns, fixed dental prostheses and implant-supported proshtheses), focusing on the incidence of framework fracture and chipping of the veneering porcelain

- Evaluation of the use of PEEK for implant-supported fixed and removable restorations

- Research on use of PEEK in digital prosthodontics:

3. OTHER ACTIVITIES RELATING TO PROFESSIONAL DEVELOPMENT

In order to optimize the teaching and research activity, a future project consists in the elaboration of training guides, which will systematize the stages of making dental prostheses, from the simplest to the most complex, emphasizing the technological particularities that could help specialists to avoid a series of errors leading to defects of cast, acrylic and composites resins prosthetic devices..

I also propose the elaboration of a guide of good practices in the dental laboratory, which should be useful to dentist and dental technicians in order to avoid cross-infection..

1. Member in the project Prevention of school dropout and counseling in choosing the career path for first year students of Dental Medecine and Dental Technique (Be.MeDTech)
2. Member in the project "Insertion of medical graduates on the labor market, through the development of internships in practical training of practical skills-MEDPRO"

Educational projects will represent another part of my activity since and I already participated as a member in an educational projects dedicated to 1st year students of the Faculty of Dental Medicine - Prevention of school dropout and counseling in choosing the career path being in unfavorable situations (BeMedTech), and and another project dedicated to graduates from the final years (VI-th year, Dental Medecine specialization and III-rd year, Dental technique specialization- Insertion of medical graduates on the labor market, through the development of internships in practical training of practical skills-MEDPRO ". These projects have helped us to better understand the problems that students face and to help them more effectively in their training activity.

In conclusion, my future teaching and research activity will aim at training high-level specialists, encouraging young researchers in developing and finalizing projects, creating a strong research core with interdisciplinary teams.

The results of our research will be published in prestigious journals and presented at national and international congresses, which will contribute to increasing the visibility and prestige of the Faculty of Dentistry.

Section D

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