SUMMARY
PhD THESIS

STUDIES OF PERIODONTAL BIODYNAMICS DURING ORTHODONTIC THERAPY ASSOCIATED WITH PERIODONTAL DISEASE

SCIENTIFIC COORDINATOR
Prof. Dr. Silvia MÂRŢU

PhD STUDENT
Alexandru-Ionuţ LUCHIAN
# TABLE OF CONTENTS

## GENERALITIES

INTRODUCTION, MOTIVATION ................................................................. 1

## CHAPTER I

APPLICATIONS OF THE FINITE ELEMENTS METHOD IN THE RESEARCH OF ORTHO-PERIODONTAL BIODYNAMICS ........................................ 3

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.1. Introduction</td>
<td>3</td>
</tr>
<tr>
<td>I.2. The methodology of the finite elements analysis</td>
<td>4</td>
</tr>
<tr>
<td>I.3. The advantages of FEM</td>
<td>7</td>
</tr>
<tr>
<td>I.4. General applications of FEM</td>
<td>7</td>
</tr>
<tr>
<td>I.5. The applications of FEM in dental medicine</td>
<td>7</td>
</tr>
</tbody>
</table>

## CHAPTER II

INTERRELATIONS BETWEEN PERIODONTAL PATHOLOGY AND ORTHODONTIC TREATMENT ................................................................. 9

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>II.1 General information</td>
<td>9</td>
</tr>
<tr>
<td>II.2 Periodontal response to orthodontic forces</td>
<td>10</td>
</tr>
<tr>
<td>II.3 The influence of orthodontic therapy on diseased periodontal</td>
<td></td>
</tr>
<tr>
<td>structures</td>
<td></td>
</tr>
<tr>
<td>II.3.1. Orthodontic tooth migration with loss of periodontal support</td>
<td></td>
</tr>
<tr>
<td>tissue</td>
<td></td>
</tr>
<tr>
<td>II.3.2. The influence of orthodontic forces on the inflamed</td>
<td></td>
</tr>
<tr>
<td>periodontal ligament</td>
<td></td>
</tr>
<tr>
<td>II.4. Orthodontic treatment characteristics that can induce periodontal</td>
<td></td>
</tr>
<tr>
<td>functional pathology</td>
<td>14</td>
</tr>
<tr>
<td>II.5. Specific premises of orthodontic treatment</td>
<td>17</td>
</tr>
</tbody>
</table>

## CHAPTER III

BIOLOGY AND IMMUNO-HISTO-CHEMISTRY OF PERIODONTAL BIODYNAMICS IN ORTHODONTIC THERAPY ................................................................. 20

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>III.1. Physiological dental migration</td>
<td>20</td>
</tr>
<tr>
<td>III.2. Orthodontic dental migration</td>
<td>20</td>
</tr>
<tr>
<td>III.2.1. The biological reaction of the alveolar bone during</td>
<td>21</td>
</tr>
<tr>
<td>orthodontic dental migration</td>
<td></td>
</tr>
<tr>
<td>III.2.2. Periodontal remodelling: the tension zone</td>
<td>25</td>
</tr>
<tr>
<td>III.2.3. Mechanisms of biological control in dental migration</td>
<td>29</td>
</tr>
</tbody>
</table>

## CHAPTER IV

FEM STUDIES ON THE BIODYNAMICS OF DISEASED PERIODONTAL TISSUE UNDER ORTHODONTIC FORCES ................................................................. 38

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV.1. Introduction</td>
<td>38</td>
</tr>
<tr>
<td>IV.2. Objectives</td>
<td>38</td>
</tr>
<tr>
<td>IV.3. Materials and method</td>
<td>39</td>
</tr>
<tr>
<td>IV.3. Results</td>
<td>44</td>
</tr>
</tbody>
</table>
IV.3.1. Simulated molar uprighting in the context of periodontal pathology .......................................................... 45
IV.3.2. Simulated intrusion on frontal upper and lower groups in the context of periodontal pathology .................. 56
IV.3.3. Simulated palatinization and lingualization of upper and lower frontal groups in the context of periodontal disease .... 84
IV.4. Discussions .......................................................................................................................... 112
IV.5. Conclusions ...................................................................................................................... 118

CHAPTER V.
A COMPARATIVE CLINICAL STATISTICAL STUDY BETWEEN THE PERIODONTAL STATUS BEFORE AND AFTER ORTHODONTIC THERAPY .................................................................................................................. 120
V.1. Introduction .......................................................................................................................... 120
V.2. Objectives ............................................................................................................................ 121
V.3. Materials and method ......................................................................................................... 121
V.4. Results ..................................................................................................................................... 122
V.5. Discussions .......................................................................................................................... 152
V.6. Conclusions .......................................................................................................................... 162

CHAPTER VI.
A STUDY ON THE CELLULAR BIOLOGICAL RESPONSE IN AFFECTED PERIODONTAL TISSUES – THE RESULT OF ORTHODONTIC FORCES 163
VI.1. Introduction ........................................................................................................................ 163
VI.2. Objectives ........................................................................................................................... 164
VI.3. Materials and method ......................................................................................................... 164
   VI.3.1. Harvesting and preparing the biological material, saliva .................................................. 164
   VI.3.2. The principle of the ELISA immunodetection test .......................................................... 166
   VI.3.3. The method variants .................................................................................................... 167
   VI.3.4. Action protocol ........................................................................................................... 170
   VI.3.5. Determining IL1-β ...................................................................................................... 174
      VI.3.5.1. Materials and method ............................................................................................ 174
      VI.3.5.2. Results ................................................................................................................. 175
   VI.3.6. Determining the level of MMP-9 .................................................................................. 181
      VI.3.6.1. Materials and method ............................................................................................ 181
      VI.3.6.2. Results ................................................................................................................. 181
   VI.3.7. Determining prostaglandin-E2 .................................................................................... 187
      VI.3.7.1. Materials and method ............................................................................................ 187
      VI.3.7.2. Results ................................................................................................................. 187
   VI.4. Discussions ...................................................................................................................... 193
VI.5. Conclusions ........................................................................................................................ 194

GENERAL CONCLUSIONS ............................................................................................................. 195
THE ORIGINALITY OF THE RESEARCH AND PRACTICAL APPLICATIONS OF THIS STUDY ................................................................. 197
BIBLIOGRAPHY ............................................................................................................................ 201
INTRODUCTION

The present research started from the idea that the purpose of any orthodontic treatment is not only to improve facial aesthetics and dento-maxillary functionality, but also to preserve the health of the periodontal support tissue because, however correct an orthodontic solution might be, there is always a chance of periodontal liability. The short-term and long-term aims of any orthodontic treatment are influenced by the patient’s periodontal status before, during, and after an active orthodontic treatment.

The orthodontist must always be able to recognize the clinical forms of the periodontal inflammatory disease and the etiological factors involved in the emergence of periodontal pathology; interdisciplinary cooperation is extremely beneficial in establishing a diagnosis and the correct and complete therapy plan. Such interdependence between orthodontics and periodontology is crucial if we consider the fact that, in many cases, the periodontal condition is improved by dental migration whereas orthodontic treatment is often facilitated by periodontal therapy.

I have considered this to be a useful topic for doctoral research because it has aroused a special interest in the recent literature. There have been numerous professional controversies at various dates, so I think this is a good opportunity to explore some new directions of research.

Taking the above as my starting point, I think it is necessary to expand the research on the interrelations between periodontology and orthodontics in order to improve the treatment goals. Orthodontic therapy must correct the dento-maxillary anomalies, facilitate the management of some restorative and aesthetic problems, and improve periodontal health under the circumstances (Dannan, 2010). But let us not forget that, under certain circumstances, orthodontic treatment can also have a destructive potential on the periodontal anatomy as it can generate various complications (Dannan, 2010).

The topic of the present doctoral thesis is based on clinical, statistical, and microbiological studies, as well as mathematical models in the attempt to explain the relationship between orthodontic dental migration and various types of periodontal diseases. The results are in line with the data supplied by the literature which shows that a correct orthodontic treatment in patients with excellent oral hygiene and without extant severe periodontal destruction does not entail risks for the connective tissue. But in the case of precarious dental hygiene, pre-existent untreated periodontal complications, orthodontic treatment with fixed devices and orthodontic dental migration can generate significant destruction of the periodontal landscape.
PERSONAL CONTRIBUTIONS
CHAPTER IV
FEM STUDIES ON THE BIODYNAMICS OF AFFECTED PERIODONTAL TISSUE UNDER ORTHODONTIC FORCES

The objective of the study
The present research aims to compare the effect of forces of different magnitude on a pathological periodontal landscape versus a healthy tissue by trying at the same time to establish a series of practical recommendations on issues pertaining to orthodontic management, with predictable results, in patients with reduced bone mass in the context of complex oral rehabilitation. Another purpose of this research is to identify potential periodontal hazards that have not yet been clinically identified.

The proposed aims of the present research were to observe the maximal equivalent tensions for the whole tooth-PDL-bone complex with different degrees of periodontal disease, and the maximal tensions that appear on the direction of the force. Last but not least, I aimed to make a quantitative and comparative evaluation of the dental migration ensuing in different clinical scenarios replicated by mathematical modelling.

Another aim was to determine whether, in the context of certain morphological characteristics of the anterior teeth, these might respond differently to forces of equal magnitude on the same background of periodontal disease.

Materials and method
The present research with finite elements involves making three main three-dimensional models which include: a frontal superior group made of four incisors with and without periodontal disease, a frontal inferior group made of four incisors with and without periodontal disease, and a mandibular second molar with different degrees of mesial inclination and periodontal disease. The anatomical characteristics were replicated in the mathematical simulation by using a Nissin didactic life-size model with periodontal disease (www.nissin–dental.net). During modelling the following considerations were taken into account: tooth geometry and morphology, periodontal and dental arch structures, the physical properties of the teeth, periodontal ligament and alveolar bone; the magnitude and direction of the force that simulated orthodontic effort on pathological periodontal terrain as compared to healthy bone-PDL-tooth complex.

Results and discussions
Simulated molar uprighting on a affected periodontium
As the multi-varied analysis shows, recorded migration (f – r=0.957) is the parameter most affected by the applied force, followed by the tension recorded on the direction of the applied force (σ c – r=0.805), and lastly the equivalent tension within the bone-PDL-tooth complex (σ ech – r=0.796). The tension within the bone-PDL-tooth complex grows with the degree of periodontal disease and the
SUMMARY

The magnitude of the distalization force applied in order to readjust the lower second molars. The present research shows that the magnitude of the distalization force significantly influences, from a statistical point of view, both the equivalent tension and the tension on the force direction, but especially tooth migration. The multi-varied analysis allows us to rank the parameters that influence the second molar uprighting, the most important of them being the force magnitude, followed by the presence of the initial bone lysis, and lastly mesial inclination, which was not proved to have a statistical relevance to the tension values in the observed system. In the case of healthy molars we showed that initial mesial angulation does not influence the tensions appeared within the bone-PDL-tooth complex or dental migration, and does not influence or restrict molar uprighting. In the case of molars with a periodontal disease we may say that a wider angulation is likely to induce a slightly reduced periodontal load but will come with a more limited dental migration.

Simulated intrusion on upper and lower frontal groups in the context of periodontal pathology

The present research shows that, upon intrusion on the central lower incisors, the values of the equivalent tension are constant regardless of periodontal disease, for any magnitude of the applied force, but grow with the force magnitude. Upon intrusion on the lower lateral incisors, we noticed that the equivalent tension grows with the degree of periodontal disease and with the magnitude of the applied force. In the case of 33% periodontal disease, the σe values are not very different from those obtained in zero periodontal disease. In the lower frontal group, the tension on the direction of the σc force grows exponentially depending on the applied force whether the parodontium is affected or not. Dental migration by intrusion grows exponentially with the magnitude of the applied forces, but also with periodontal disease caused by horizontal bone lysis; it can even double in the case of 66% periodontal disease as compared to 33%. The magnitude of the intrusive forces on the lower frontal group influences mainly the values of the equivalent tension, then the tension on the force direction, and lastly the movement of the lower central incisor; but it first influences the tension on the force direction, then the equivalent tension and finally the movement of the lower lateral incisor.

Simulated intrusion on the upper frontal group in the context of periodontal disease

In the upper frontal group, the σe values grow exponentially depending on the applied force regardless the periodontal disease. The σe values remain constant for each level of applied force regardless of the initial periodontal health condition.

In the case of intrusion on the upper central incisors we noticed that the σc values grow with both force magnitude and the degree of periodontal disease from 33 to 66. In the case of intrusion on the upper lateral incisors we saw that the σc values go down in the presence of periodontal disease but rise slightly with the
force magnitude and the degree of periodontal disease (from 33 to 66). In the case of a healthy periodontal landscape, in the upper frontal group, the values of $\sigma_c$ are significantly higher than those obtained on a periodontal disease. In the case of 66% periodontal disease, the movement by f intrusion, pending on the applied force, grows exponentially and has significantly higher values than those recorded for zero or 33% periodontal disease.

In the upper frontal group, the magnitude of the intrusion forces influence first the degree of movement, followed by the equivalent tension and then the tension on the force direction at the level of the central upper incisor. But for the upper lateral incisor, intrusion first influences the values of the equivalent tension, then the movement and lastly the tension on the force direction.

Simulated palatination and lingualization in the frontal upper and lower groups with periodontal disease

The present study started from the challenge of making faithful three-dimensional complex models replicating real life morphology. In terms of periodontology, molar readjustment via upbringing involves a simultaneous movement of the tooth’s connective tissue i.e., bone, ligament, soft tissue. Consequently, the mesial periodontal pouches near the tilting molar are reduced, vertical bone lysis is reduced by bone apposition on the opposite side to the movement, and also the gum architecture is improved due to diminished plaque retention. From a prosthetic point of view, molar uprighting can help resize the space in the arch and reestablish the root parallelism necessary to subsequent prosthetic reconstruction. From an orthodontic point of view, the body of a distal uprighted molar can then be moved mesially closing the posterior spaces in the arch – a difficult mechanical move involving maximum anchorage on the anterior teeth and with an optimal lateral occlusion, which was done successfully. In the present study we revealed the fact that, once the magnitude of the molar distalization force increases, all the tension values increase too (both the equivalent von Misses tensions and the tensions on the direction of the distalization force), as well as the movement of the second mandibular molars which are not mesially tilted, and of those with initial mesial inclination.

In the cases we researched, the most frequently used appliance for uprighting was the molar readjustment spring which comprises the following:

- a short superelastic posterior NiTi segment ($\beta$) of 0.016 x 0.022 connected by a sliding tube to
- a steel sectional spring of 0.017 x 0.025 ($\alpha$);
- two small precast tubes soldered perpendicularly on top of each other and applied one on the anchorage spring in the C – Pm1 region, the other vertically so as to ensure the insertion of the sectional steel spring.

In our study we noticed that, for both a 0.25 N and a 1N force there are no significant differences between tension values or tooth migration, neither in teeth with a healthy parodontium nor in molars with diseased parodontium. Also, the
angulation of the mesioinclination did not significantly influence the evolution of the tension values in the bone-PDL-tooth complex in either the healthy periodontium or the periodontium with horizontal 5.5 mm bone lysis.

For the simulated intrusion on the lower frontal group, the present study highlights the fact that, when the intrusion force increases, there appears a gradual increase of the von Misses equivalent tensions and the tensions on the force direction, as well as the amplitude of dental migration, for both the lower central incisors without initial periodontal disease and those with horizontal bone lysis of 33% and 66%. For a 0.25N intrusive force, the values of equivalent tensions remain unchanged for the healthy lower central incisor and for the cases of periodontal disease of 33% and 66%, respectively. When periodontal disease spreads, this intrusive force will gradually generate higher values of the tension on the force direction. As for dental migration, for the tooth without initial periodontal problems the periodontal ligament shifts farther during intrusion, whereas for the tooth with initial periodontal disease the tooth itself moves farther because the ligament becomes loose due to bone lysis. At the same time, dental migration doubles for a horizontal bone lysis of 66% as compared to 33%. For a 1N, 3N, or 5N intrusive force we noticed that the values of equivalent tension remain constant in the three analyzed situations; the growth of periodontal disease doubles the tensions on the force direction. In terms of movement, for the lower central incisor with healthy initial periodontium, the periodontal ligament moves during intrusion whereas for the 33% or 66% diseased incisor, it is the tooth that shifts. Moreover, dental shifting doubles when bone lysis reaches 66% as compared to 33%.

The increase of the intrusive force for the healthy lower central incisor as compared to the periodontically diseased lower central incisor determines:
- An increase of the von Misses equivalent tensions;
- An increase of the tension on the direction of the intrusion force;
- An increase of dental migration;

The comparative analysis of the lower incisor of various degrees of periodontal disease (33% and 66%) after increasing the magnitude of the intrusion force shows the following:
- Constant values of the von Misses equivalent tensions;
- An estimated 40% growth of the tensions on the force direction;
- Twice as frequent dental migration;

The comparative analysis of the intrusion on the healthy lower central incisor and the one with 33% bone lysis shows, after the forces grew in magnitude:
- Constant von Misses equivalent tensions;
- Constant tensions on the force direction;
- Constant dental migration;

The comparative analysis of the intrusion on the healthy lower central incisor and the one with 66% bone lysis shows, after the forces grew in magnitude:
- Constant von Misses equivalent tensions;
- Twofold tensions on the force direction;
- Twofold dental migration;

Upon simulated intrusion on the upper frontal group we revealed that when the intrusion force increases there appears a gradual increase in the Von Misses equivalent tensions and those on the force direction, and dental migration, both for the healthy upper central incisors and for those with horizontal bone lysis of 33% and 66%. For a 0.25N intrusive force, the equivalent tensions remain constant for the lower central incisor without periodontal disease or with 33% disease. In the upper central incisor with 66% periodontal disease the equivalent tensions rise by 25%, and the tension on the force direction rises by approximately 116% as compared to a pristine parodontium. If periodontal disease spreads, this intrusive force will determine gradually higher values for the tensions on the force direction. As to dental migration, we noticed that in a healthy tooth or in one with 33% periodontal disease, the periodontal ligament moves more during intrusion, and for the tooth with 66% periodontal disease it’s the tooth that moves more because the ligament loosens due to bone lysis. At the same time, dental migration increases by approximately 20% for a horizontal bone lysis of 66% as compared to a healthy parodontium.

We noticed that the equivalent tensions remain relatively constant for the upper central incisor under 1N, 3N, or 5N intrusive force no matter the degree of periodontal disease; the only notable change is an approximately 20% growth of these tensions in the case of a horizontal bone lysis of 66%. For the upper central incisor, the tensions on the force direction remain constant subsequent to an intrusive force of 1N, 3N, or 5N for a healthy parodontium or a 33% horizontal bone lysis. Where the parodontium is 66% diseased, these tensions are double no matter the force applied. For the healthy upper central incisor, as compared to the diseased upper central incisor, the increased intrusive force determines the following:

- increased von Misses equivalent tensions;
- increased tensions on the direction of the intrusion force;
- increased dental migration;

The comparative analysis of the upper central incisor with various degrees of periodontal disease (33% and 66%) subsequent to an increased magnitude of the intrusion force shows the following:

- constant von Misses equivalent tensions in the case of a 33% bone lysis associated with a tension increase of around 20% for a parodontium with 66% disease;
- approximately 5% increase of the tensions on the force direction for a 33% diseased parodontium, and 166% in the case of a 66% diseased parodontium;
- 20% increase of dental migration in the case of 66% diseased parodontium;
SUMMARY

The comparative analysis of the intrusion on a healthy lower central incisor and one with 33% bone lysis upon increased forces shows the following:
- constant von Misses equivalent tensions
- constant tensions on the force direction
- constant dental migration

The comparative analysis of the intrusion on a healthy lower central incisor and one with 66% bone lysis upon increased forces shows the following:
- increased von Misses equivalent tensions by 25%
- twofold tensions on the force direction
- increased dental migration by 20%

The correction of the dental malposition is undoubtedly a positive effect of orthodontic therapy on the periodontal status even though it is secondary to the control of the bacterial plaque and bacterial colonization of the parodontium. Mesial molar tipping, more frequent in the lower 2 molars, is caused by the premature loss of the permanent 1 molars as a result of a dramatic evolution of cavities and represents an aggravating factor for the localized periodontal disease in adults because of the difficulty of maintaining an adequate hygiene in the mesial area of the inclined tooth.

Conclusions

● In the case of molars without periodontal disease, we showed that initial mesial angulation does not influence the tensions occurring on the bone-PDL-tooth complex or dental migration, as it does not affect or limit the predictability of the molar uprighting.
● If we refer to uprighting molars with periodontal disease, a wider angulation will induce a slightly diminished periodontal load, but will come with a more reduced dental migration.
● The less attachment support around the tooth, the more important palatinization of the upper frontal group becomes in terms of tension in the system, movement, and, from a clinical point of view, the negative side-effects.
● The magnitude of the intrusive forces at the level of the upper frontal group influence firstly the amplitude of movement, then the equivalent tensions, and thirdly the tensions on the force direction at the level of the upper central incisor. But for the upper lateral incisor it firstly influences the equivalent tensions, then movement and lastly the tensions on the force direction.
● In the lower frontal group, the magnitude of the intrusive forces firstly influences the equivalent tensions, secondly the tensions on the force directions and thirdly the movement of the lower central incisor. But for the lower lateral incisor, it firstly influences the tensions on the force directions, then the equivalent tensions, and lastly dental migration.
● Palatinization of the upper frontal group is characterized by increased tension values: the tension on the direction of the force for the central incisors, and the equivalent tension for the bone-PDL-tooth for the lateral incisors. Movement by
palatinization of the upper frontal group does not significantly associate with the magnitude of the applied force.

- Lingualization of the lower frontal group is characterized by the fact that none of the analyzed parameters is significantly influenced statistically by the magnitude of the applied force, the tension on the direction of the force, the equivalent tension at the level of the bone-PDL-tooth complex, or dental migration.
- Due to the root’s morphological characteristics and the differences in diameter at cervicular level, the present study reveals a significant periodontal risk in the case of the lingualization of the lower lateral incisor, as compared to the lower central incisor, with the so-called feather effect.

CHAPTER V
COMPARATIVE CLINICAL STATISTICAL STUDY BETWEEN THE PERIODONTAL STATUS BEFORE AND AFTER ORTHODONTIC THERAPY

Objectives
To assess the adequacy of pre-treatment oral hygiene at the site and make correlations with age and types of anomalies;
To analyze the type of periodontal disease before treatment and establish correlations with the patient’s age and the types of dental malocclusions;
To study the influence of the type of orthodontic treatment on the periodontal condition during orthodontic treatment;
To study the degree of periodontal disease after the treatment focusing on the improvement or deterioration of the periodontal condition depending on age, the type of Angle class, crowding-spacing, overjet, and overbite;

Materials and method
The type of study. The aim of the present research is to make a longitudinal etiological, prospective, and incidence follow-up study.
The sample includes 495 patients who received orthodontic and periodontal care in 2010-2014 in three private clinics from the cities of Iași, Rădăuți, and Pașcani. They were treated interdisciplinarily by the same medical team i.e., orthodontist and periodontist.

Results and discussions
The patients had vestibular gum recession on the lower frontal group. The analysis of the patients’ observation sheets allows the following conclusions regarding the etiological factors – whether developmental or acquired:
- A highly vestibularized eruption of the tooth caused by the lack of space in the anterior region of the arch with a reduction of the inter-canine space
- An excessive inclination of the tooth in the vestibular direction in the context of insufficient space or as a consequence of harmful habits
- High insertion frenula that cause traction
Plaque deposits that cause localized chronic gingivitis

- The magnitude and direction of orthodontic forces
- Excessive use of 2\textsuperscript{nd} class elastic bands
- The decision against extraction in the situations of thin periodontium

During orthodontic treatment, some teeth with a normal amount of attached gum may undergo localized vestibular recession most likely caused by excessive forces that can push the tooth outside the cortical bone. This recession subsequent to dental migration is often an area with no inflammation, which explains the fact that orthodontic movement occurred towards the areas with attachment deficiency or was excessive, as it happens in some situations after orthognathic surgery or after maxillary disjunction. On this background, a chronic marginal gingivitis can easily destroy the alveolar bone and the gum attachment even though the orthodontic forces are mild.

Of the orthodontic factors that encourage gum recession, vertical and sagittal incisive occlusion is paramount to me. Thus, in severe deep-bite, the periodontium of the lower frontal teeth are affected on the vestibular side, and sometimes the upper ones on the palatinal side. Also with regard to the vertical direction, we must not overlook the fact that head-to-head occlusions can generate forces that push gum attachment to the minimum, thus enhancing the destructive effect of the inflammatory process. In the sagital plane, at the beginning of the treatment we cannot overlook crossbites or severe vestibularization; a superficial therapy plan that ignores the periodontal context can have disastrous effects.

From my clinical experience, a thin periodontium is more likely to undergo recession during orthodontic treatment as compared to a normal or thick periodontium. That is why it is necessary to take measures in order to prevent attachment loss subsequent to orthodontic movement. In the case of thin periodontium, these measures may include grafts of epithelial and connective tissue at the beginning of the orthodontic treatment. The results of the previous study (the finite elements method) show that the lower incisors with some periodontal pathology have the most significant periodontal risk during orthodontic movement. The lower lateral incisor has a significantly higher risk as compared to the lower central incisor because of some specific morphological elements. This aspect has never before been identified in the literature.

The sample includes 495 patients, 169 male and 326 female, most of them children (66%), fewer teenagers (13%) and adults (20%). 1.52% had temporary dentition, 74.39% mixed dentition, and 24% - permanent. In this sample, most of the anomalies are class I Angle (54.14%), followed by class II/1 (21.62%), class II/2 (15.15%) and class III (9.09%). As for the associated anomalies, dental crowding occurs with the upper teeth in teenagers, the lower teeth in adults, and bimaxillary in teenagers. Dental spacing appears with the upper teeth mainly in children, with the lower teeth in teenagers, and bimaxillary in adults. Normal
overjet appears in 52.32% of the patients, and 1/3 overbite in 26.46%; and ½ overbite is prevalent due to young age.

Pre-treatment oral hygiene was correct in 56.25% of teenagers and 39.81% of adults. Statistical results indicate that incorrect pre-treatment oral hygiene was most frequent in patients with localized dental crowding on both arches. We identified an inadequate pre-treatment oral hygiene in 335 out of 495 patients, many of whom had a variety of anomalies: class I Angle (48%), class II/1 Angle (24%), class II/2 Angle (18.5%), and class III Angle (9.5%). Also, we noticed an inadequate pre-treatment oral hygiene in 505 of the patients with normal overjet and 23.88% of those with normal overbite. In 167 cases we studied the pre-treatment periodontal disease; these were the teenagers and adults. We noticed a pre-treatment periodontal disease in 80% of the sample, most of which being gingivitis (34%). The age distribution shows periodontal disease in 57.81% of the teenagers (mostly gingivitis), and 93.2% of adults (mostly gingivitis, pouches, and recession). With regard to the degree of dental crowding, pre-treatment periodontal disease is more frequent in patients with bimaxillary crowding while dental spacing is associated with periodontal disease especially if it occurs on the upper jaw.

In our sample, the pre-treatment periodontium is diseased in 45% of the patients with class I Angle anomalies, 23% of the patients with class II/1 Angle, about 20% of the patients with class II/2 Angle, and 12% with class III Angle. We also noticed a pre-treatment diseased periodontium in 60% of the patients with normal overjet and 30% of those with normal overbite, but in higher proportions in the patients with enlarged overbite. With regard to the influence of the type of orthodontic treatment on the periodontal condition, the present study shows that mobile devices maintain periodontal health in 57% of the patients whereas fixed devices and a combination of surgical and orthodontic therapy are the most frequent factors of periodontal deterioration (33%-36% of the cases). After orthodontic treatment, the periodontal health condition is influenced by the following:
- the type of anomaly: periodontal deterioration is most frequent in class III, then in class I, and class II/2, while periodontal improvement is most frequent in class III, followed by class II/2.
- initial dental crowding: periodontal deterioration is most frequent in the patients with lower crowding, while improvements occur in fairly equal proportions for all three types of crowding.
- overjet/overbite: periodontal deterioration occurred especially in the group with negative sagital inocclusion, open occlusion and 1/1 overbite, while periodontal improvement occurred after the correction of frontal underbite, of an overjet wider than 7 mm, of deep underbite and overbite.
- age: post-treatment periodontal deterioration occurred especially in adults as compared to teenagers, while improvements were noticed in fairly equal proportions in both adults and teenagers.
The present research has shown that, in this sample, periodontal disease decreased from 79% pre-orthodontic treatment to 73% post-treatment especially in what concerns recession, pouches and gingivitis. Depending on age, post-treatment periodontal status indicated a significant statistical decrease of the number of periodontal pouches in teenagers, but also an increased incidence of gingivitis, whereas in adults it featured a higher incidence of recession and gingivitis but also a lower incidence of periodontal pouches. Age in itself does not represent a counterindication for orthodontic treatment. Aging comes with a decrease in cell activity, and a bigger amount of collagen in the periodontal tissue, which slows down the therapeutic response to orthodontic forces as compared to children and teenagers. From my personal experience, there is a direct relationship between periodontal health and the tissue response to orthodontic dental migration. In the absence of bacterial plaque orthodontic forces do not cause gingivitis; but if plaque is present during orthodontic dental migration it may entail loss of attachment tissue and bone lysis. Teenagers treated with fixed devices rarely experience new periodontitis or an aggravation of a pre-existing periodontal condition. The patients with other forms of gingivitis should not have orthodontic therapy before the etiological factor is completely removed.

**Conclusions**

- In patients with periodontal disease, bone lysis results in a diminished area of periodontal ligament, so the same force applied at the crown level will cause a bigger pressure on the periodontal ligament of a diseased tooth as compared to a healthy one. In other words, on a tooth with periodontal pathology only very mild forces can be applied.
- In adults, orthodontic treatment can be used on healthy or diseased periodontal structures with a few inevitable but light side-effects (e.g., radicular resorption) if orthodontic forces are maintained within biological limits, if periodontal inflammation is meticulously kept under control, and oral hygiene is maintained thoroughly over the entire active phase of dental migration.
- Generally speaking, it is recommended that periodontal treatment precede orthodontic treatment because, in the presence of inflammation, periodontal destruction caused by orthodontic forces is inevitable and often irreversible.
- Dental scaling, root planing, subgingival curettage and grafts of epithelial and connective tissue must be done before the debut of dental migration.
- The corrective phase of periodontal treatment: eliminating periodontal pouches, or correcting bone defects, can be postponed until the end of orthodontic treatment because dental migration can modify the bone and gum morphology.
- Polishing and containment are essential in adult patients; for those with periodontal problems previous to orthodontic treatment, containment must be maintained over the entire lifetime.
CHAPTER VI
A STUDY ON THE CELLULAR BIOLOGICAL RESPONSE IN AFFECTED PERIODONTAL TISSUES – A CONSEQUENCE OF ORTHODONTIC FORCES

Objectives
The aim of this study was to comparatively assess the differences between the levels of the following inflammatory biomarkers: cytokines (IL-1β), prostaglandins (E2), and metalloproteinases (MMP-9) in patients with orthodontic devices and stabilized pre-existing periodontal pathology (chronic periodontitis localized in at least teeth) versus patients of the same pathology but without orthodontic treatment.

The objective of this research was to describe the biological processes occurring at molecular level at the time of applying orthodontic forces on a affected parodontium, to establish the role of orthodontic treatment in periodontal therapy and last but not least to identify the markers that can most accurately indicate the level of inflammation in periodontal tissue.

Materials and method
In a first stage we obtained the approval of the commission for research ethics of Grigore T. Popa University of Medicine and Pharmacy in order to harvest saliva, and the informed consent of the 60 selected patients. The sample was divided into three groups as follows: the control group A comprising 16 patients without periodontal disease or clinical gum abnormalities, group B comprising 22 patients with periodontal disease (chronic periodontitis localized in at least three teeth) with periodontal treatment, and group C comprising 14 patients with periodontal disease (chronic periodontitis localized in at least three teeth) with orthodontic and periodontal treatment. Saliva was harvested twice from groups B and C as in the following: For group B there was an initial harvest followed by a second one six months after completing periodontal therapy. For group C there was an initial harvest and a second one six months after periodontal stabilization and the beginning of orthodontic therapy. For both groups, periodontal therapy was the same and included scaling above and under the gum, as well as root planing.

Results and discussions
The novelty of the present study is the fact that we compared three different inflammatory markers in different clinical situations, and we tried to make pertinent associations between the statistical data, the clinical situation, and the administered therapy. If most previous research focused on determining interleukin-6 (IL 6) or metalloproteinase-8 (MMP-8), the present research focused on quantifying prostaglandin-E2 (PGE2), interleukin-1β (IL-1 beta), and metalloproteinase-9 (MMP-9), which represents a new element.

During our research, we compared the levels of IL-1β function of the type of therapy and Angle class. We noticed that after associated therapy the levels of
IL-1β drop significantly lower (they were higher before treatment). The levels of IL-1β were significantly lower in patients who received associated therapy as compared to those who only received periodontal therapy. It is important to note that at the beginning of therapy the patients who were assigned for periodontal and orthodontic therapy had higher levels of IL-1β.

**Conclusions**

- After associated therapy (periodontal and orthodontic), the levels of all inflammatory markers in saliva (IL-1β, MMP-9, and PGE2) dropped significantly more than those measured after single therapy.
- An important aspect ensuing from the comparison of the post-therapy IL-1β levels highlights the fact that, in associated therapy, post-therapy levels drop significantly more for all Angle classes, and they are higher in patients of Angle class III.
- After associated therapy, MMP-9 levels drop significantly more in Angle class II/2 and class II/1 malocclusions where they were significantly higher before treatment. We also noted significant changes in patients with Angle class III malocclusions.
- The association of the two therapies (periodontal and orthodontic) caused a significant statistical drop of the PGE2 levels, which indicates an obvious reduction of the inflammation and an improved periodontal status, but the present study has not revealed a significant correlation between the levels found in saliva after the associated therapy and the type of malocclusion.
- The results of the present study indicate MMP-9 as a strong candidate for the assessment, via saliva, of inflammation of the diseased periodontal tissue that also takes the impact of orthodontic forces. Apparently, MMP-9 is the most accurate marker to indicate the level of inflammation associated with the type of malocclusion and therefore it represents an excellent instrument of diagnosis for monitoring periodontal evolution during orthodontic treatment.

**GENERAL CONCLUSIONS**

- Interdisciplinary (ortho-periodontal) collaboration represents an indispensable way to obtain the best results from an aesthetical and therapeutic point of view, as well as the patient’s satisfaction. An accurate interdisciplinary ortho-periodontal diagnosis is crucial in establishing the timing of periodontal therapy and its stages. Depending on the case, we can combine various surgical and orthodontic techniques in order to ensure periodontal health before, during, and after orthodontic therapy.
- Periodontal disease can be aggravated by orthodontic therapy, but for patients who have some periodontal disease orthodontic therapy is indicated in order to correct or alter local factors, such as malpositioned teeth that make oral hygiene difficult, in order to redirect functional forces along the long dental axis, in order to
improve the gum and bone landscape, to correct the dental axis, and to resize the space within the arch in view of a correct prosthetic recovery.

● The mathematical models we used in this study highlight the fact that the loss of bone support does not have a negative impact on dental migration in the diseased periodontal tissue that take moderate (close to optimal) forces.

● Due to some root morphological characteristics and the differences in cervical diameters, our study reveals a significantly higher periodontal risk during the lingualization of the lower lateral incisor, as compared to the lower central incisor, which comes with the “feather effect.”

● The clinical and statistical data show that age in itself does not represent a counterindication for orthodontic therapy. In patients with periodontal disease, bone lysis results in a diminished area of periodontal ligament, so the same force applied at crown level will cause a bigger pressure on the periodontal ligament of a diseased tooth as compared to a healthy one. In other words, on a tooth with periodontal pathology only very mild forces can be applied.

● In adults, orthodontic treatment can be used on healthy or affected periodontal structures with a few inevitable but light side-effects (e.g., root resorption especially in female patients) if orthodontic forces are maintained within biological limits, if periodontal inflammation is meticulously kept under control, and oral hygiene is maintained thoroughly over the entire active phase of dental migration.

● The level of saliva cytokines shows that, after associated therapy (periodontal and orthodontic), the levels of all inflammatory markers found in saliva (IL-1β, MMP-9, and PGE2) decreased significantly more in comparison with the levels recorded after periodontal therapy alone.

● If we compare the levels of MMP-9 function of the type of therapy and Angle class, we may conclude that, after associated therapy, MMP-9 levels drop significantly more in Angle class II/2 and class II/1 malocclusions where they were significantly higher before treatment. We also noted significant changes in patients with Angle class III malocclusions.

● The results of the present study indicate MMP-9 as a strong candidate for the salivary assessment of the level of inflammation in the affected periodontal tissues under the action of orthodontic forces. Apparently, MMP-9 is the most accurate marker to indicate the level of inflammation associated with the type of malocclusion and therefore it represents an excellent instrument of diagnosis for monitoring periodontal evolution during orthodontic treatment.
SELECTIVE BIBLIOGRAPHY


Davidson RM, Tatakis DW, Auerbach AL. Multiple forms of mechanosensitive channels in osteoblast-like cells. Pflugers Arch 1990; 416:646 – 651.


