THE EVALUATION OF THREE DIFFERENT COMPOSITE RESINS USED FOR PERIODONTAL SPLINTS: AN ULTRAMORFOLOGICAL ANALYSIS

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ABSTRACT

The purpose of this study was to evaluate the characteristics of three types of composite resins used for periodontal immobilization systems' realization, the G-aenial Flo X (GC Corporator—Tokyo, Japan), the GrandioSO (VOCO—Cuxhawen, Germany), and the Clearfil Majesty ES flow (Kuraray Noritake Dental Inc.—Okayama, Japan). The structural analyses were realized by scanning electron microscopy, using a QUANTA 200 3D scanning electronic microscope (FEI, Netherlands), and the determination of the elemental composition of the materials was realized via X-ray spectroscopy with energy dispersion (EDX). The results showed that the GrandioSO composite demonstrated the most resistant nonporous structure, due to the presence of a homogeneous matrix characterized by low proportions of silicon and carbon. Further research is required in order to analyze the mechanical parameters of these resins and their behavior in different biological environments, in vitro and in vivo.

Key words: *composite resins; periodontal immobilization systems; fiber glass strips; ; X-ray spectroscopy*

INTRODUCTION.

Periodontal disease is a form of infectious pathology that develops when bacteria in tooth plaque interact with a vulnerable host [1-4]. Because of the inflammatory response, periodontal fibers become disorganized, bone resorption is induced, and epithelial cell attachment is disrupted [5,6]. In addition, occlusal stresses matter because they can accelerate a periodontal lesion if they are strong enough to overcome a deficient attachment system [7,8].

As a result, loss of periodontal attachment can promote tooth movement and migration, which can produce unequal occlusal pressures, disrupting the delicate balance between bone resorption, bone repair, and periodontal fiber rearrangement [9]. Diagnosis and intervention, including occlusal improvements and tooth splinting, can help eliminate or reduce tooth movement in natural dentition [10]. The connecting of teeth in a splint system is an essential strategy for reducing mobility in circumstances with decreased periodontal support [11,12]. There are now a multitude of splinting techniques and materials in use. When choosing the appropriate type of immobilization for the case, special attention must be paid to recreating patients' comfort.In restoring the affected functions, mainly the masticatory function, the decision must be made between increased mobility and not increasing health of the periodontal tissues.[13] Elasticity, flexural tension, and hardness are properties that can influence the loading stress on immobilized teeth [14-16].

By redistributing the stresses that would otherwise be borne by the mobile tooth to its immovable neighbors, splinting can improve comfort, function, and esthetics by allowing the periodontium to reconnect and the mobile tooth to live longer[17,18]. Composite materials are used to realize immobilization devices, and the longevity of the splints, functional rehabilitation, and patient comfort depend on the mechanical parameters and the surface condition of these resins [19-22]; moreover, the porosity and roughness of the materials are closely related to microbial adhesion, with a direct impact on periodontal health [23-25]. Scanning electron microscopy (SEM) combined with energy dispersive X-ray spectroscopy (EDX) can provide interesting details about the surface properties of materials through examination of their ultramorphology [26]. There is insufficient long-term data on splinted teeth [27-29]. Moreover, these findings are varied and very ambiguous, displaying both high survival rates (such as splints in lower anterior teeth) [30] and poor survival rates (in both upper and lower anterior teeth) [30]. Also uncertain is the effect of splinting on tooth prognosis [31]. As an alternative to metal wires, composite resin materials have a high elastic modulus, good esthetics, are flexible, and may adhere chemically to both the tooth and the composite material, making them ideal for stabilizing hypermobile teeth that compromise chewing function [32].

Therefore, the purpose of this research was to perform SEM and EDX investigations to compare the surface properties of three different composite resins used in periodontal immobilization system [33].

MATERIALS AND METHODS

The research focused on the analysis of some resins frequently used in practice for periodontal splints, the G-aenial Flo X, the GrandioSO, and the Clearfil Majesty ES flow.

To create the samples, rectangular wax patterns, 15 mm in length, 4 mm in width, and 2.5 mm in thickness were made [14]. An impression of the wax patterns was realized, with Elite Double fluid silicone (Zhermack, Badia Polesine, Italy), in order to obtain a mold. The material had an excellent elasticity, due to the final hardness of the 8 Shore A, total precision in reproducing detail, and dimensional stability. Once mixing the base and the catalyst at a ratio of 1: 1 for 60 seconds, the paste was spread over the wax models; after the reaction and hardening of the material was complete, around 20 minutes later, the wax patterns were removed, and the mold was created, with the proper dimensions.

The composite resins were optimized by introducing glass fibers into their structure (Interlig, Angelus). Glass fibers are extremely fine strands of silica-based glass that have been extruded into a very narrow thread. Glass fiber-reinforced composites are made by encasing glass fibers in a resin matrix.

Composite resins were cast from negative images of wax patterns using a mold. The calibrated slots for each sample were then coated with a thin layer of composite fluid, and fiberglass was then mixed into the composite resin. The fibers, which had the dimensions of 8.5 cm × 2.0 mm × 2.0 mm, were sectioned and calibrated to the sample dimensions (Figures 1). Then, a new fluid composite layer was applied on the surface of the fiber, positioning the insert in the mass of the composite, in order to reinforce it. Finally, the sample was light-cured for 40 s using a Voco Celalux 2 light-curing device.

There were 18 samples taken, 6 from each composite resin type; they were placed in plastic tubes and color-coded as follows: red for the heavy-flow composite GrandioSO, yellow for the G-aenial Flo X fluid composite, and blue for the Clearfil Majesty ES flow fluid composite.

The evaluation of the dimensional parameters' accuracy of the samples was performed using a Directa®® Iwansson™ Measuring Devices-Model I (Marletta Enterprise, Naxxar, Malta), a high precision instrument for confirming the wall thickness of prosthetic crowns. This tester instrument is made of high-quality steel, thus eliminating the risk of wear error.

The surfaces of the restorative composite resins were gently polished with sandpaper sheets (Fuji Star 1000-, 2000-, 4000-, 6000-, and 10,000-grit, Sankyo Rikagaku Co., Saitama, Japan), such that the fillers were exposed for observation under SEM. Subsequently, a grinder polisher (Minimet 1000, Buehler, Lake Bluff, IL, USA) was used by adding 6-µm and 0.025-µm diamond pastes for 10 min (MetaDi II, Diamond Polishing Compound, Buehler). The surfaces were also slightly etched with a solution of 0.8% (wt/vol) H3PO4 for 10 s to obtain a clearer image during SEM observation. After this, the specimens were ultrasonically cleansed for 5 min, placed on aluminum stubs with conductive tape, coated with osmium for 10 s (HPC-1S, Vacuum Device, Ibaragi, Japan), and observed under SEM (S-4500, Hitachi, Tokyo, Japan) with backscattered electron signal [30,31].

The samples were prepared for structural analysis and to determine the elemental composition of the materials using X-ray spectroscopy with energy dispersion (EDX).

The microstructural analysis of the composite resins was made using a QUANTA 200 3D scanning electronic microscope (FEI Netherlands). Scanning Electron Microscopy (SEM) is an effective method for detection of high-resolution structural images; in our study, the following parameters were used for the sample analysis: low vacuum mode; LFD (large field detector), spot size: 5, 10 kV, working distance: 15 mm.

For EDX analysis, the samples of 15 × 4 × 2.5 mm were placed on a stab-type support on a carbon strip, coated with osmium for 5 s, and analyzed using EDX (Super Xerophy, S-817XI, Horiba Stec, Kyoto, Japan), which was attached to the SEM. An area of approximately 25 × 20 µm was selected for 2D analysis, which included both the resin matrix and the filler particles. The relative values were obtained after five minutes of measurement.

The quality of the results depends on the signal strength and the cleanliness of the spectrum. The signal strength relies heavily on a good signal-to-noise ratio, particularly for trace element detection and dose minimization.

RESULTS

Three distinct types of resins were distinguished by their surface appearance when seen at 100, 500, 1000, and 2000x magnifications (Figures 1–4).

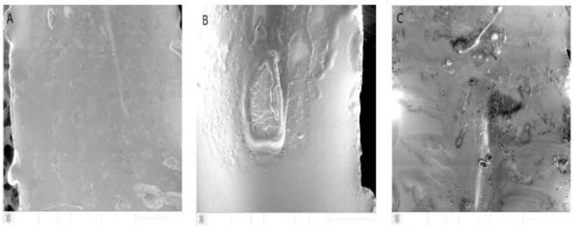

***Figure 1.** SEM images of the composite surface at 100× magnification: (**A**) GrandioSO; (**B**) Clearfil Majesty ES flow, and (**C**) G-aenial Flo X*

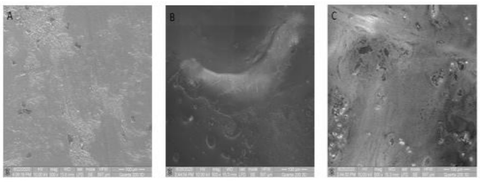

Figure 2. *SEM images of the composite surface at 500× magnification: (**A**) GrandioSO; (**B**) Clearfil Majesty ES flow, and (**C**) G-aenial Flo X*

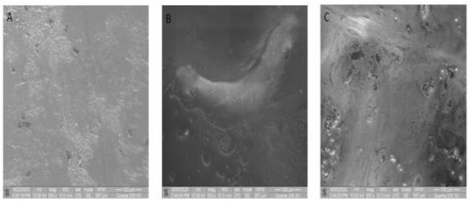

Figure 3. *SEM images of the composite surface at 1000× magnification: (**A**) GrandioSO; (**B**) Clearfil Majesty ES flow, and (**C**) G-aenial Flo X*

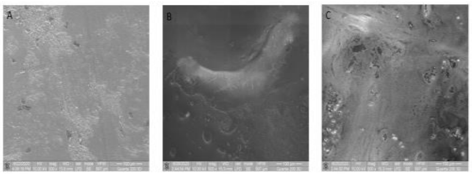

Figure 4. *SEM images of the composite surface at 2000× magnification: (**A**) GrandioSO; (**B**) Clearfil Majesty ES flow, and (**C**) G-aenial Flo X*

Thus, the Clearfil Majesty Es flow composite resin, which contains a filling material of the smallest dimensions compared to the other two nanocomposites (Grandio SO and Gaenial Flo X), shows a more uniform surface aspect and a heterogenous structure, with denser areas and pores of micron dimensions.

In agreement with the increase of magnification, the accentuated rugosity of the composite surface is seen on the surface of the Grandio SO composite; a moderately rugous surface is seen on the surface of the G-aenila Flo X composite and a relatively continuous surface is seen in case of the Clearfil Majesty Es flow composite.

EDX provided us with data on the atomic ratio, allowing us to determine the relative abundance of each element in the matrix and so get insight into the distinctive biomaterial composition.

Element	***Wt%***	***At%***
CK	12.16	25.19
OK	24.83	38.62
CoL	01.42	00.60
AlK	07.27	06.71
SiK	27.00	23.93
BaL	27.33	04.95
Matrix	Correction	ZAF

Figure 5.*EDX composition for Clearfil Majesty ES flow*

Element	***Wt%***	***At%***
CK	21.51	37.38
OK	30.26	39.48
AlK	04.94	03.82
SiK	21.54	16.01
BaL	21.75	03.31
Matrix	Correction	ZAF

Figure 6*EDX composition for G-aenial Flo X*

Element	Wt%	At%
CK	06.19	12.05
OK	34.87	50.92
AlK	05.31	04.60
SiK	35.21	29.29
BaL	18.42	03.13
Matrix	Correction	ZAF

Figure 7. EDX composition for G-aenioSO

DISCUSSION

Coordination of pretreatments and a suitable prosthetic plan for patients requiring extensive periodontal and prosthetic therapy requires an interdisciplinary approach. Further, novel dental materials and methods can be useful in addressing complex dental issues [3,32]. According to research by Kathariya et al., splints are frequently used to minimize the chance of subsequent traumatic occlusion on periodontally compromised teeth and to better distribute occlusal stresses [8,33,34]. Moreover, research carried out by Liu et al. showed that splinting abutment teeth with different materials led to a dramatic decrease in the stress values in periodontal tissues [35]. Soares et al. demonstrated that the main objective of stabilizing teeth with a splint was the reduction in the biomechanical stresses in the supporting bone structure [36].

However, other research has shown no evidence that splinted teeth are more likely to be lost than natural teeth. The prognosis of periodontally damaged teeth is not improved by splinting, although it can assist their retention by reducing their mobility. Positive effects of nonsurgical periodontal therapy were seen, with a probable trend toward even greater benefits from splinting mobile teeth, particularly with respect to restrictions placed on the patient's ability to bite and chew [37-44].

Fibers can improve a composite resin's performance in two primary ways. Stress is distributed along the length of the fibers. This improves the brittleness of the composite matrix. Second, the strength of the material is improved by the fibers' ability to prevent fractures and redirect cracks. The doctor must create a system that can optimally tolerate all potential failure modes. Each mechanism operates differently depending on the orientation of the load.

Composite resins are notoriously difficult to analyze, although from a broad standpoint, energy dispersive electron spectroscopy (EDX) study provided some useful data on the structural aspects of resins [10]. Common constituents found in all of the tested resins were carbon, oxygen, aluminum, silicon, and barium. The sole material distinction was observed in the fluid composite Clearfil Majesty ES flow, which, in addition to the previously described ingredients, also displayed Co in its structure.

Splinted teeth will only last as long as the materials and techniques used to create them. The loading strains put on the splint during normal and parafunction have led to the conclusion that a large proportion of splinted teeth experience complications, that repairs are required around 75% of the time, and that almost half of the splints require maintenance every year [45,46].

As a result of our observations, we came to the same findings as Eftime et al. in their research [47], which is to say that the addition of Si C was the factor that influenced the emergence of pores in the structure of the composite resin, thus being a high risk factor of plaque accumulation, in accordance with other studies [1,46,48]. The thermal characteristics of the samples were drastically altered by the incorporation of the Si C, with the expansion coefficient shifting downward to provide stability against thermal shocks.

Additionally, splinting may prevent the need for tooth extraction and elaborate, costly prosthodontic therapy [48,49]. Due to the irreversible nature of bone loss from severe periodontitis, the splint must be durable, stable, effective, physiologically safe, and simple to design, produce, and apply. Esthetics, plaque management, and periodontal health must also be maintained [50-52].

CONCLUSIONS

Despite the study's limitations, it was determined that Grandioso composite resin exhibited the most homogenous and nonporous structure. however, the Clearfil Majesty es flow resin had a greater silicon oxide content, which raised the resin's porosity and, by implication, the possibility of microbiological contamination.

After weighing the pros and cons of the three materials under consideration, we conclude that the grandioso has the best chance of producing durable periodontal immobilization devices thanks to its use of glass fiber reinforcement.

Though the materials explored here are suitable for periodontal splinting, there is need for improvement in our understanding of the mechanical properties, biological properties, and clinical behavior of laboratory-fabricated periodontal splints for the purposes of rehabilitation. further research is required, in order to analyze the mechanical parameters of these resins and the behavior in different biological environments, in vitro and in vivo.

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