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COMPARISON BETWEEN ENAMEL DEMINERALIZATION AROUND DIFFERENT BRACKET TYPES (IN VITRO STUDY)

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Abstract

Objective: *The objective of this study was to compare between enamel demineralization around stainless steel brackets, metal flash-free brackets and ceramic flash-free brackets.*

Materials and Methods: *Forty natural teeth were divided in a random manner into four groups of equal size. The first group, denoted as the control group, comprised non-bonded teeth. The second group included stainless steel brackets bonded with a conventional light-curing adhesive. The third group consisted of adhesive coated metal flash free brackets bonded to teeth. Finally, the fourth group consisted of adhesive coated ceramic flash-free brackets that were bonded to teeth. After bonding, demineralization at the gingival side of the brackets was measured using a diagnodent pen. Teeth in all groups were subsequently subjected to demineralization to develop artificial carious lesions. A second measure for demineralization was recorded for each group. The demineralization values of the four groups were subjected to statistical analysis using One-Way ANOVA test followed by pot Hoc LSD analysis between every two groups.*

Results: *Before the process of demineralization, there were insignificant differences among the four groups (P=0.784). Following the process of demineralization, significant differences became apparent among the four groups, with group II demonstrating a higher value in comparison to groups III and IV (P< 0.001).*

Conclusions: *The enamel demineralization level was higher around conventional brackets when compared to flash-free brackets. Both metal and ceramic flash free brackets showed similar amounts of enamel demineralization around them.*

Keywords: *Flash free Brackets; Demineralized enamel; Diagnodent*

Introduction

Enamel decalcification or demineralization is a significant clinical concern commonly observed during orthodontic treatment. The use of fixed appliances in orthodontic therapy complicates maintenance of oral hygiene and enhances the risk of enamel lesions. (1)

White spot lesions (WSLs) are commonly identified as occurrences of subsurface enamel demineralization, indicating the early phase of caries formation. The occurrence of white spot lesions (WSLs) is relatively high, with a prevalence rate above 25% among individuals undergoing orthodontic treatment. During the course of their treatment, it is frequent for these individuals to develop at least one new lesion. (2)

The process of demineralization can manifest rapidly, as seen by certain cases where it has been observed as early as four weeks after the placement of brackets, with the possibility of

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remaining for several years following the end of treatment. During the initial phases, surfaces are undamaged when gently probed. However, cavitation may take place when there is a persistent cariogenic challenge, perhaps leading to the necessity of invasive restorative procedures. (3)

The utilization of bands and brackets attached to the teeth in fixed orthodontic treatment leads to adherence of plaque and food particles to the enamel surfaces of teeth, which are recognized to possess an elevated susceptibility to caries formation. (4)

The mouth muscles and saliva's inherent cleansing mechanism is constrained by the existence of irregular surfaces on brackets, bands, and wires. Moreover, the existence of orthodontic attachments presents difficulties in terms of mechanical plaque elimination by the patient. (5,6)

Precoated flash-free brackets had been presented with promising clinical advancements, including decreased bonding time and elimination of excess adhesive removal, as well as smooth brackets and adhesive margins. The successful achievement of these objectives relied on the application of an adhesive possessing a low filler content, low viscosity, and excellent wettability. This adhesive was enclosed within a nonwoven polypropylene fiber mat, which was precisely cut and attached to the bracket base. (7)

Few research in the literature examined the the sequelae of utilizing metal and ceramic flash free brackets on enamel demineralization. Accordingly, this study was conducted to compare enamel demineralization around conventional stainless steel, metal flash free brackets and ceramic flash free brackets. The null hypothesis was that there would be no differences in enamel demineralization between the four groups.

Materials And Methods:

Ethical approval:

This research had been authorized by the Research Ethics Committee of Faculty of Dentistry, Minia University. (Decision number 795/2023)

Sample Size Calculation:

The sample number necessary for each group was settled using G Power 3.1 9.2 software (Franz Faul,Universitat Kiel, Germany) after a power calculation according to the data obtained from a previous study.(8)In that study, the mean demineralization values in the upper first premolar at gingival side immediately after bonding and following demineralization were 5.7±2.53 and 3.87±1.55 respectively using conventional brackets, that was statistically significant . A sample size of 10 teeth in each group was required to provide 80% power for mean difference for two matched pairs at the level of 0.05 significance.

The Sample:

The study samples included extracted human natural teeth Forty extracted permanent first premolar teeth were collected from the outpatient clinic of orthodontic department, Faculty of Dentistry, Minia University, Egypt.

The criteria for selecting the teeth were the following:

- **Recently extracted human natural teeth.**
- **The integrity of the buccal enamel of the teeth was preserved.**
- **No fractures were observed during the extraction procedure.**
- **The teeth did not display any carious lesions.**
- **No enamel defects on buccal surfaces.**

With a sharp blade, all hard and soft tissue remnants were removed and rinsed away with tap water. Following that, the teeth were placed in distilled water till the experiment began. A round plastic mold with an interior diameter of 10mm was created. To cover the interior surface of the mold, a separating medium agent was used. A self-curing acrylic resin (acrosun, Northjamalzade, Tehran, Iran) was used to fill the mold. The mold was placed on a glass slab to achieve a levelled and smooth surface base. Each tooth was vertically inserted into the acrylic resin within the mold, with the tooth crown protruding above the mold's surface. (Figure 1).

Figure (1): Tooth surrounded by acrylic resin mold

Bonding protocol

Before the bonding process, the buccal enamel surfaces were subjected to polishing using a mixture of fluoride-free pumice and water. The polishing procedure was conducted with a rubber polishing cup for a period of 10 seconds.

The forty teeth were split into four equal groups randomly:

For group I, teeth enamel was not treated or bonded.

For group II, the enamel surfaces underwent a 30-second etching procedure utilizing a 37% phosphoric acid solution (Mega Etch, Mega Biodent, Korea). The teeth were rinsed using water for a period of 10 seconds, followed by a subsequent drying process using oil-free compressed air for an additional 10 seconds. In all cases, the etched enamel exhibited a frosty white appearance. A coating of primer (3M Unitek, Monrovia, CA, USA) was carefully applied over the etched area of the teeth using a nylon brush. A small amount of adhesive was

applied to the bottom of the bracket. The stainless-steel brackets (3M Unitek Dental Products, Monrovia, CA) were applied to the tooth with a uniform force in the middle middle third. The excess adhesive encircling the base of the bracket has to be meticulously and cautiously eliminated using a scaler, while ensuring the bracket remains undisturbed. The curing equipment was utilized at a light intensity of 1000 milliWatt per square centimetre (mW/cm2) for a period of 10 seconds in each direction (mesial, occlusal, distal, gingival) utilizing a LED curing light (3M Unitek Dental Products, Monrovia, CA).

For group III (metal flash free, 3M Unitek Dental Products, Monrovia, CA) and IV (ceramics flash free, 3M Unitek Dental Products, Monrovia, CA) brackets were bonded similar to group II with the exception of no adhesive application to the brackets. This was due to the presence of adhesive on the brackets, according to the specifications provided by the manufacturer.

Following the bonding technique, the teeth were kept in distilled water at 37°C for 24 hours to allow full polymerization of the bonding material.

Measurement of enamel demineralization:

Enamel demineralization around different bracket types was measured utilizing the laser fluorescence device (diagnodent). The Diagnodent device (DD) (Kavo, Biberach, Germany) employd a 655-nano meter (nm) monochromatic light that was emitted from a tip/sensor in order to identify back-scattered fluorescence originating from the tooth (figure 2). Fluorophores with a wavelength of 655 nm have been identified as bacterial porphyrins. The DD scale depicts a numerical range that extends from 0 to 99. According to this scale proposed by Lussi et al. (1999), which was subsequently updated by Pinelli et al. [9], The established criteria for classifying lesions are shown in table 1.

Table 1. Clinical criteria for visual examination of the diagnodent device

0-12	Low risk for caries progression
13-24	Medium risk for caries progression
More than 25	High risk for caries progression

Figure (2) Diagnodent pen (KaVo, Biberach, Germany).

Artificial caries-like lesions:

The specimens were immersed in a 10 mL solution solution (Phthalate buffer SDFCL, 29034L05, sd fine-chem limited, industrial estate, worli road, Mumbai) with a pH value of 4.3, keeping a temperature of 37°C for 96 hours (Figure 3). The solution was changed at regular intervals of 4 hours. Untreated enamel specimens were immersed in the demineralization solution for 96 hours. would result in the development of enamel lesions measuring 100 micrometers in depth and represent approximately 3 months of real time. [10] In order to address the possible buildup of fluoride in the solution, the cariogenic solution was periodically refreshed every 4 hours. [10]

After artificial cares like lesion were evoked, a second measure of enamel demineralization was taken for all groups.

Figure (3) samples in incubator at 37°C

Statistical Analysis:

The data gathered were collected, tabulated and statistically analyzed using:

A- One Way ANOVA test for quantitative data between the 4 groups followed by pot Hoc LSD analysis between every two groups.

B- Paired Samples T-test to compare quantitative data between before and after demineralization in each group

RESULTS

As regards demineralization before treatment, there were insignificant differences between the four groups (p-value = 0.784). In group I, the mean scores for enamel demineralization were 3.3 and the standard deviation was 0.9. In group II, the mean scores for enamel demineralization were 3.4 and the standard deviation was 1.1. In group III, the mean scores for enamel demineralization 3.4 and the standard deviation was 1. In Group IV, the mean scores for enamel demineralization were 3.1 and the standard deviation was 1.1 (Table 2 and figure 4).

Table 2: Demineralization scores of the four groups before immersion in the demineralizing solution.

	Group I	Group II	Group III	Group IV	P-value
	N=10	N=10	N=10	N=10	
Scores before demineralization	(2-5) [a] 3.3±0.9	(2-5) [a] 3.4±1.1	(2-5) [a] 3.4±1	(2-5) [a] 3.1±1.1	0.784

- Data expressed as (range) and mean ± SD.
- One Way ANOVA test for quantitative data between the 4 groups followed by pot Hoc LSD analysis between every two groups.
- Superscripts with different small letters refer to a significant difference between every two groups.
- Superscripts with the same small letters refer to insignificant difference between every two groups
- *: Significant level at P value < 0.05

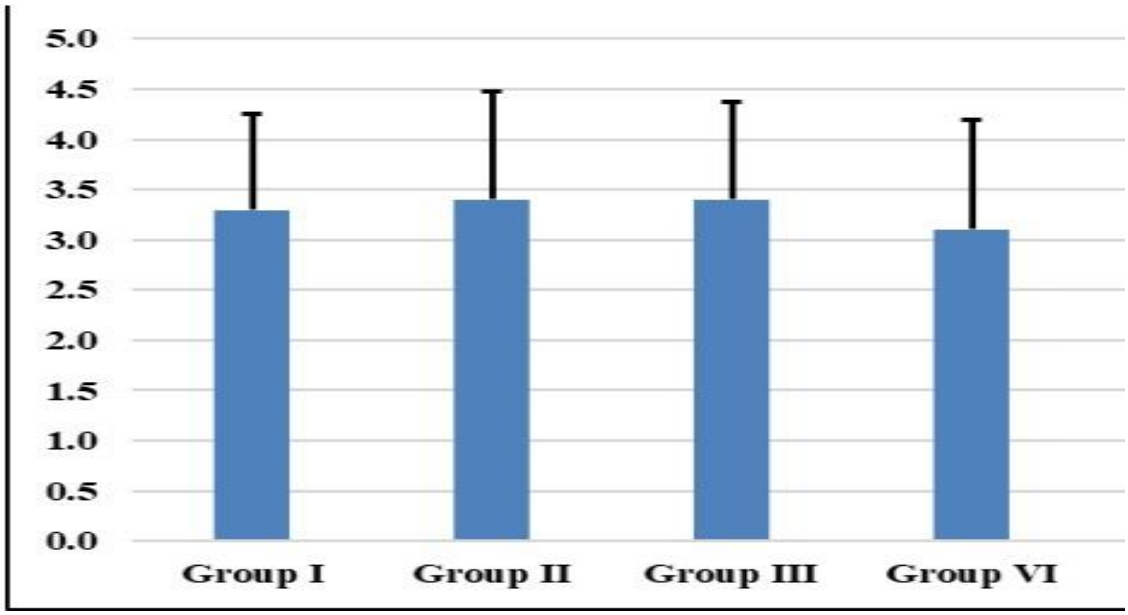

Figure 4: Demineralization scores before immersion in demineralizing solution

As regards demineralization after treatment, there were significant differences between the four groups. Group II showed the highest demineralization score followed by group III and IV "with insignificant difference between both (Table 3 and figure5).

Table 3: Demineralization scores between the four groups after immersion in demineralizing solution

	Group I	Group II	Group III	Group IV	P value
	N=10	N=10	N=10	N=10	
Demineralization after immersion in demineralizing solution	(7-10) [d] 8.4±0.8	(14-17) [a] 15.6±1	(12-15) [b] 13.6±1.1	(12-15) [b] 13.7±1.1	**<0.001***

- Data expressed as (range) mean ± SD.
- One Way ANOVA test for quantitative data between the 4 groups followed by pot Hoc LSD analysis between every two groups.
- Superscripts with different small letters refer to a significant difference between every two groups.
- Superscripts with the same small letters refer to insignificant difference between every two groups
- *: Significant level at P value < 0.05

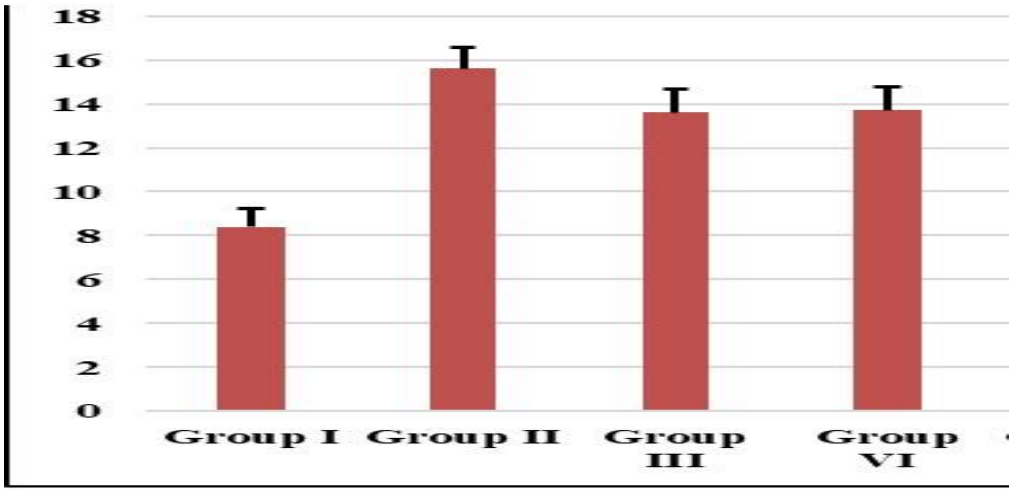

Figure 5: Demineralization scores after immersion in demineralizing solution

Regarding the demineralization differences, significant difference was observed among the four groups. Specifically, group II exhibited the highest value, followed by groups III and IV, with no significant difference observed between the latter two groups. In group I, the mean scores for enamel demineralization were 5.1 and standard deviation was 1. In group II, the mean scores for enamel demineralization were 12.2 and standard deviation was 1.1. In group III, the mean scores for enamel demineralization were 10.2 and standard deviation was 1.2. In group IV, the mean scores for enamel demineralization were 10.6 and standard deviation was 0.8 (table:4 and figure 6).

Table 4: Demineralization difference between the four groups

	Group I	**Group II**	**Group III**	**Group IV**	**P value**
	N=10	**N=10**	**N=10**	**N=10**	
Demineralization Difference	(3-6) [d] 5.1±1	(11-14) [a] 12.2±1.1	(9-13) [b] 10.2±1.2	(9-12) [b] 10.6±0.8	**<0.001***

- -The data is presented in the form of a range, with the mean value being reported together with its corresponding standard deviation.

- -The study employed a One-Way Analysis of Variance (ANOVA) to assess the quantitative data across the four groups. Subsequently, a post hoc Least Significant Difference (LSD) analysis was conducted to compare each pair of groups.

- - Superscripts denoted by distinct lowercase letters indicate a statistically significant difference between each pair of groups.

- The significance level is set at a P value of less than 0.05.

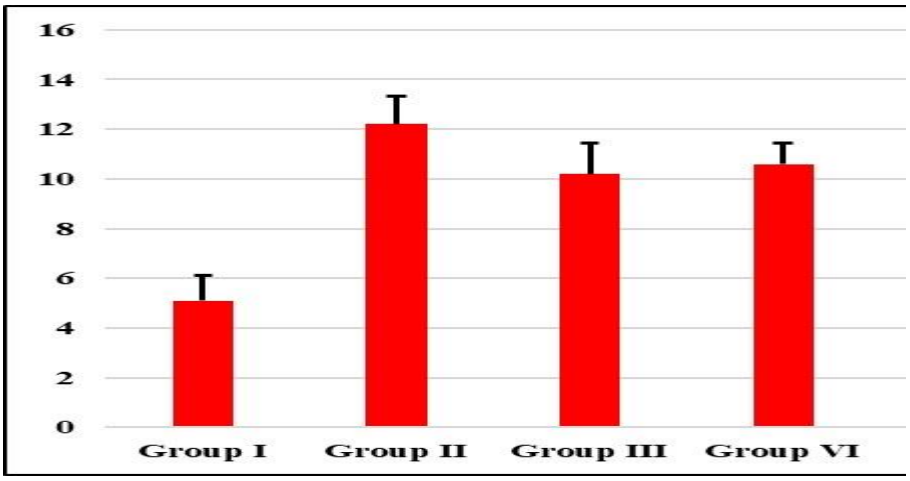

Figure 6: Demineralization difference between the four groups

Comparing demineralization before and after treatment, It was found that there was significant increase in demineralization after treatment within each group. In group I, before demineralization the mean scores for enamel demineralization were 3.3 and standard deviation was 0.9. After demineralization the mean scores for enamel demineralization were 8.4 and standard deviation was 0.8. In group II, before demineralization the mean scores for enamel demineralization were 3.4 and standard deviation was 1.1. After demineralization the mean scores for enamel demineralization were 15.6 and standard deviation was 1. In group III before demineralization the mean scores for enamel demineralization were 3.4 and standard deviation was 1. After demineralization the mean scores for enamel demineralization were 3.6 and standard deviation was 1.1. In group IV before demineralization the mean scores for enamel demineralization were 3.1and standard deviation was 1.1 After demineralization the mean scores for enamel demineralization were 13.7 and standard deviation was 1.1 (table: 5 and figure 7)**.**

Table 5: Comparison of demineralization between before and after immersion in demineralizing solution in each group

	Demineralization		**P value**
	Before	**After**	
Group I	(2-5) 3.3±0.9	(7-10) 8.4±0.8	**<0.001***
Group II	(2-5) 3.4±1.1	(14-17) 15.6±1	**<0.001***
Group III	(2-5) 3.4±1	(12-15) 13.6±1.1	**<0.001***
Group IV	(2-5) 3.1±1.1	(12-15) 13.7±1.1	**<0.001***

- Paired Samples T-test for quantitative data between Before and after treatment in each group

- *: Significant level at P value < 0.05

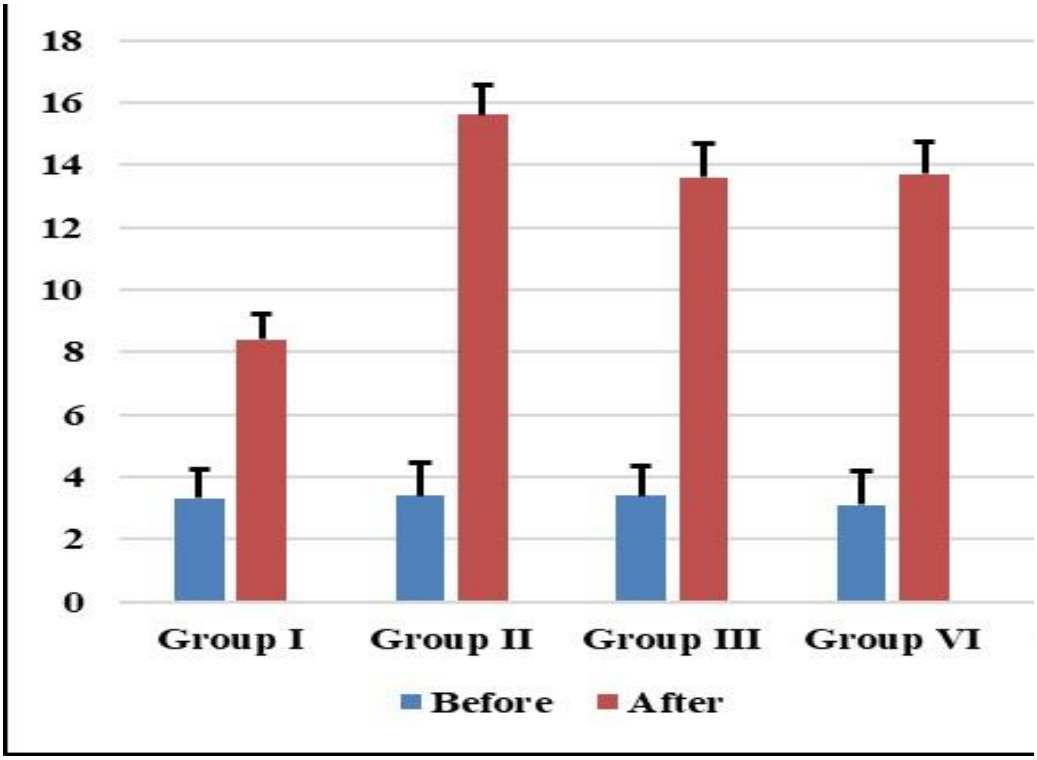

Figure 7: Comparison of demineralization between before and after immersion in demineralizing solution

DISCUSSION

Demineralization is defined as the depletion of minerals or mineral salts from the structure of the tooth. The term "demineralization" is seen as more encompassing and precise in comparison to its alternative, as it recognizes that the elimination of calcium is not the exclusive substance implicated in these phenomena. (11)

The phenomenon of enamel demineralization has been seen to occur rapidly, with documented instances of mineral depletion occurring shortly after the initiation of orthodontic treatment. Enamel demineralization is primarily influenced by three factors: the mineral component of the enamel, the production of bacterial plaque, and the dietary habits of the patient. (12)

The process of enamel demineralization is initiated by a decrease in oral pH, which caused by acidogenic bacteria found in dental plaque that produce acids through the breakdown of carbohydrates during their metabolic activities. White spot lesions frequently occur in close proximity to orthodontic brackets due to the buildup of plaque in the surrounding area. (13)

This study used distilled water as a storage medium because it was inspired by a prior study that examined the effects of four different storage solutions on bovine enamel. The findings of the study indicate that water was found to be the most commonly favored storage solution due to its limited impact on the enamel substrate over a prolonged duration, in comparison to saline, thymol, and artificial saliva solutions. (14)

Numerous strategies have been utilized in modern adhesive systems with the objective of reducing enamel demineralization. The combination of adhesive solutions with sealers is a common practice aimed to achieve a smooth surface. The use of brackets with precoated adhesive is one technique to addressing the demineralization process that occurs on tooth surfaces. This procedure ensures that the correct quantity of adhesive is applied to the bracket base, so minimizing the occurrence of excess adhesive and subsequently decreasing the accumulation of bacteria. (15)

In addition, the development of precoated brackets has been accompanied by advancements in adhesive techniques, resulting in the birth of brackets referred to as APC PLUS. The aforementioned objects are coated in a pre-existing adhesive compound that creates a flash upon placement. The object exhibits a pink color before undergoing the process of light polymerization, so aiding the orthodontist in the removal of excess material. During the process of light polymerization, the adhesive undergoes a chromatic transition, where its color changes from pink to a transparent. In a study done in 2007, Armstrong et al. compare conventional brackets and APC plus brackets and found that the utilization of staining on the adhesive did not result in a decrease of remnant flash. (16)

Flash Free adhesives use an adhesive solution with a nonwoven mat which is saturated with resin adhesive. When pressed on the enamel surface, the translucent and low-viscosity resin produces a channeling border around the bracket's edges. This intriguing technique, according to the company, is realized by a nonwoven polypropylene fibre mat that is immediately positioned on the bracket's base. This mat has been saturated with a low-viscosity resin. The mat's aim is to be somewhat compressible when placed against the tooth while holding back excess glue that is squeezed out during bracket application. (17)

Furthermore, the transition in morphology from a bracket to a tooth is distinguished by the inclusion of a chamfer, which serves to enhance the cleanliness of the implanted appliance. Previous study has been undertaken by the manufacturer 3M to investigate the multiple improvements associated with the FF adhesive system. Jung et al. conducted a comparative investigation of the morphology of the APC PLUS flash and FF brackets in their study. The researchers concluded that there were no statistically significant differences between the two bracket types. The adhesive layer thickness did not differ significantly between the FF brackets and APC PLUS. When compared to the APC PLUS brackets, the thickness of the adhesive layer in

the FF brackets was found to be greater, but also more homogenous. [18]

Furthermore, this research findings align with the observations obtained by Ludwig Hennig et al. where in both APC flash free brackets and conventional adhesive brackets exhibited demineralization, which was found to be more evident when compared to teeth that were not bonded with brackets but modern FF adhesive systems contribute to less enamel demineralization during orthodontic treatment. [19]

The current study presents empirical evidence that supports the effectiveness of the flash-free technique in mitigating enamel demineralization, in comparison to the APC plus technique. The outcomes of this investigation were in line with the findings of Almosa et al. (2017), who discovered that the depths of demineralization Were 112.96 +83.45 and 149.95+118.64 for FF and APC PLUS respectively. This indicate that flash-free brackets exhibited lower levels of enamel demineralization compared to traditional brackets with glue. [20]

Grünheid and Larson (2019) have posited that the FF adhesive offers time-saving benefits subsequent to orthodontic treatment. The removal of the brackets resulted in a notable reduction of 20% in the quantity of adhesive residue, thereby leading to a drop in the level of effort needed for the removal of the adhesive. [21]

The laser fluorescence (LF) technique was created as a tool to enhance the early identification of dental caries. The non-invasive methodology holds significant value in the timely detection of hidden caries in teeth that have not yet developed cavities. The light that is released has a wavelength of 655 nm within the infrared region of the electromagnetic spectrum. The present illumination possesses the capacity to be assimilated by both organic and inorganic compounds present within dental structures. Consequently, the phenomenon of remitted fluorescence demonstrates a spectrum of values ranging from 0 to 99, denoting distinct degrees of fluorescence. A caries lesion can be distinguished by a numerical number equal to or greater than 20 or 25. [22]

Really. The Diagnodent device is an excellent tool for detecting demineralization processes in smooth enamel lesions. [23]

One of the limitations of this study was that it was an invitro one. Accordingly, future in vivo studies are recommended to evaluate the advantages of flash free brackets. Additionally, this study was performed on premolar teeth only. Therefore, the results should not be generalized for other teeth with different anatomy.

Conclusions

The flash free brackets showed less enamel demineralization around them than conventional stainless-steel brackets. Both metal and ceramic flash free brackets showed similar amount of enamel demineralization around them

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