

IMPACT OF CLEAR ALIGNERS AND DIFFERENT ESTHETIC ORTHODONTIC BRACKETS ON ENAMEL DEMINERALIZATION (A COMPARATIVE SEM STUDY)

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ABSTRACT

Objective: To evaluate the susceptibility of development and severity of enamel surface demineralization with subsequent development of white spot lesions (WSLs) in patients treated with clear aligners in comparison with those treated with monocrystalline and poly crystalline ceramic brackets (using scanning electron microscope).

Methodology: Forty sound permanent premolars were collected from 4 groups of patients (n=10). **Group I:** patients received no orthodontic treatment (control group), **group II:** patients treated with polycrystalline ceramic brackets, **group III:** patients treated with monocrystalline ceramic brackets, **group IV:** patients treated with clear aligners. The buccal surfaces of teeth were coated with gold and subjected to scanning electron microscope (SEM) surface analysis and Elemental analysis of calcium and phosphorus using energy-dispersive X-ray spectroscopy (EDX).

Result: The polycrystalline, monocrystalline and clear aligner groups showed demineralization with significant decrease in both calcium and phosphorus content ($P < 0.001$) accompanied by erosion of enamel surface. Group II was the mostly affected one, while group IV was least affected either in surface morphology or mineral loss.

Conclusion: Clear aligners showed less enamel demineralization and surface alteration in comparison with other fixed esthetic orthodontic brackets.

KEYWORDS: White spot lesions; enamel demineralization; clear aligners.

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INTRODUCTION

The main goal of orthodontic treatment is to establish a balance between structural, functional and esthetics adjustment of teeth and occlusion.⁽¹⁾ Unfortunately, enamel demineralization is an unpleasant problem related to fixed orthodontic mechanotherapy, particularly whenever accompanied by bad oral hygiene, the acidic bacterial output accumulated in plaque is accountable for the sub surface enamel demineralization, porosity and white spot lesions (WSLs) formation.⁽²⁾

Alteration in the oral cavity via fixed orthodontic appliances placement produces multiple stagnation sites.⁽³⁾ Studies have also revealed that fixed orthodontic treatment can result in resting or slowing down the salivary flow rate in some patients which lead to lowering of the PH and subsequent decrease in the buffering action and increase in colonization of *S. mutans* and *Lactobacilli*.^(3,4)

White spot lesions are manifested as chalky white opacity which occurs as a result of alterations in light spread in porous and decalcified enamel⁽⁵⁾, it could induce caries thereby bringing about bad appearance and patient resentment.⁽²⁾

Their prevalence is three folds higher in patients having orthodontic appliances compared to patients not wearing them.⁽⁶⁾ These lesions may be formed as early as four weeks following mechanotherapy beginning⁽⁷⁾, and their predominance in orthodontic patients may rise to ninety-six percent.⁽⁸⁾ The labio-lingival part of the lateral incisors represents the most prevalent place for WSLs, while the maxillary posterior areas represent the least prevalent places with greater affection in males than females.⁽⁹⁾ WSL appears in accordance with brackets, arch wires and orthodontic components that interfere with ordinary hygienic standards, causing extensive plaque aggregation.⁽¹⁰⁾

Esthetic orthodontics represent the new era in this field, and esthetic concerns persist the forefront for patients seeking orthodontic treatment and a motivating factor; many attempts were done

to develop aesthetic orthodontic appliances that optimize both esthetics and hygiene.

Ceramic brackets are esthetic brackets synthesized from either monocrystalline or polycrystalline aluminum oxide. The considerable difference between both types is represented in the optical clarity. Monocrystalline ceramic brackets are less translucent than polycrystalline brackets. Both types of ceramic brackets are harder than stainless steel brackets.⁽¹¹⁾

Unlike fixed esthetic appliances, removable appliances like clear thermoplastic aligners (CAs) are comfortable and more esthetic; they can be taken out and thus giving the patient a chance to practice oral hygienic measures and preserving his oral health.⁽¹²⁾ As a result, there is an increased demand for this treatment option among patients.⁽¹³⁾ To evaluate the proficiency of (CAs), all aspects of this therapeutic option regarding its hygienic measure like enamel demineralization must be analyzed.

So the aim of the present work is to assess ultrastructurally (using scanning electron microscope) the susceptibility of development and severity of enamel surface demineralization with subsequent development of WSLs in patients treated with clear aligners in comparison with those treated with esthetic fixed appliances as information about this point is deficient in literature.

MATERIALS AND METHODS

Sample size calculation:

It was based on mean Ca and phosphorus level between different groups retrieved from previous internal pilot on 5 samples within each of the following groups ; control , polyesthetic , monoesthetic and Clear aligners . Using G power program version 3.1.9.7 to calculate sample size based on effect size of 0.56 that yield the highest possible sample size ,using 2-tailed test, α error = 0.05 and power = 80.0%, the total calculated sample size was 40, (ten in each group).

Study design:

Forty sound permanent premolars were utilized in the study. They were assembled from 4 groups of patients (10 each). **Group I:** patients received no orthodontic treatment (control group), **group II:** patients treated with polycrystalline ceramic brackets bonded to the premolars, **group III:** patients treated with monocrystalline ceramic brackets bonded to the premolars, **group IV:** patients treated with clear aligners with composite resin attachments bonded to the premolars surface.

Teeth in group I were extracted for periodontal purpose, while in other groups they were collected from the orthodontic patients at the Faculty of Dentistry, Mansoura University, who were scheduled for extraction of their premolars after three months of treatment and received hygienic instructions. Extracted teeth were voluntary donated by the patients after writing informed consent. The research protocol was approved by the Ethical Committee of Faculty of Dentistry (No. A0107024OR).

The teeth were cleaned with periodontal currettes after rinsing with deionized water to eliminate any debris, then storage was done in 0.1% thymol solution and 4°C till utilization.⁽¹⁴⁾ The teeth were dried with air spray for 30 seconds and examined visually with LED light and magnifying loupes × 3.5 (Amtech, America) to find out any enamel surface imperfection.⁽¹⁵⁾ We excluded premolars with buccal surface cracks and stains.

The buccal surfaces of the specimens were coated with gold (25 nm thickness in 60 seconds) using (Spi Sputter Coater USA) Coating System, the metal coating makes samples conductive, then they were examined micro morphologically under scanning electron microscope (SEM; JEOL JSM6510LV). The images were attained utilizing a secondary electron detector (Everhart–Thornley) at 10 mm distance with magnification 500 X and 2000X and high voltage of 30 kV.

Energy-dispersive X-ray spectroscopy (EDX Oxford X max 20 made in England) was utilized for quantitative elemental analysis of the enamel

mineral content. The calcium and phosphorus weight percentages were evaluated using the EDX detector in a histogram plot. The scanning electron microscopic micro morphological analysis and the EDX elemental analysis were performed in the Em-unit, Mansoura University.

Statistical analysis:

Data analysis was carried out utilizing SPSS software, version 26 (SPSS Inc., PASW statistics for windows version 26. Chicago: SPSS Inc.). Qualitative data were expressed as number and percent. Quantitative data were expressed as mean± Standard deviation for normally distributed data after testing normality utilizing Shapiro Wilk test. Results were statistically significant at $p \leq 0.050$. One Way ANOVA test was utilized to compare more than two independent groups with Post Hoc Tukey test to detect pair-wise comparison.

RESULTS***Micromorphological analysis.***

SEM of the control group showed smooth enamel surface free from any pitting or pores with preserved surface integrity. (**Fig.1 a & b**)

The polycrystalline, monocrystalline and clear aligner groups showed demineralization and erosion of enamel surface represented by areas of porosities, pitting and irregularities with different degrees and depth.

Loss of enamel architecture with pronounced pitting, microporosities, and surface irregularity (honey comb like structure) resulting from the destruction of the prism core and the dissolution of enamel crystals was clearly observed in the polycrystalline group. (**Fig.1 c& d**)

The monocrystalline group showed surface irregularities but the pitting was less than that found in the polycrystalline group. (**Fig.1 e& f**)

The lowest level of surface irregularities and pitting was observed in the clear aligner group, the keyhole pattern of the enamel rods was partially preserved. (**Fig. 1 g& h**)

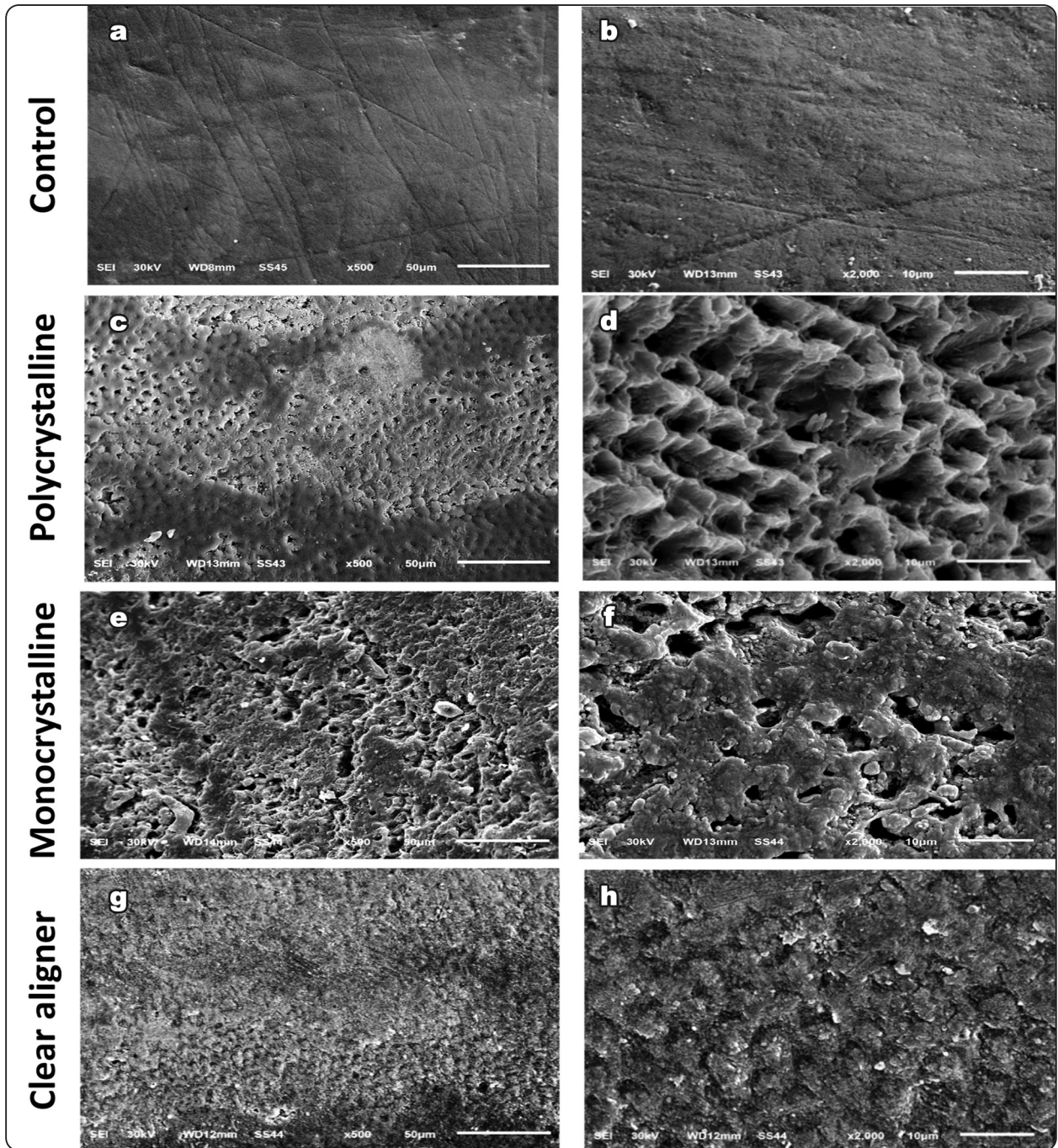


Fig. (1). SEM micrographs of control group (a&b), polycrystalline group (c&d), mono crystalline group (e&f), clear aligner group (g&h). (500X & 2000X)

EDX elemental analysis (microanalysis) of enamel surface:

Mineral analysis revealed changes in the levels of Ca and P of enamel among groups II, III and IV. There was a significant decrease in both calcium and phosphorus content ($P < 0.001$) in all the treated groups in comparison to the control one. The clear aligners group was the least one in mineral loss in comparison with both polycrystalline and monocrystalline groups. There was also a significant difference in the Ca/P ratio ($P < 0.001$) between groups II, III, IV and the control group.

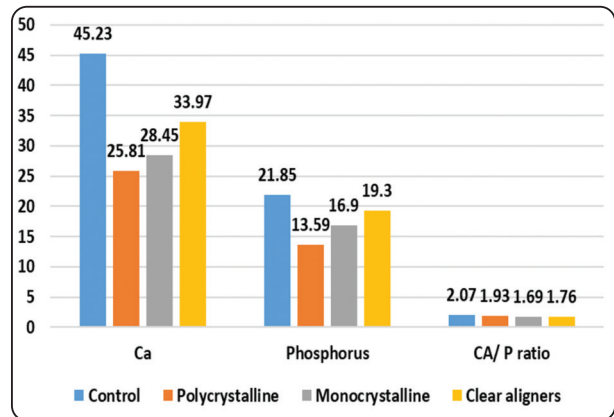


Fig. (2). Bar chart showing comparison between calcium and phosphorus contents in the studied groups.

TABLE (1) Mean and standard deviation of Calcium and Phosphorus content weight percentage and Ca/ P ratio among the different groups.

	Group I Control N=10	Group II Polycrystalline N=10	Group III Monocrystalline N=10	Group IV Clear aligners N=10	Test of significance
Ca	45.23±0.68	25.81±1.26	28.45±0.58	33.97±0.57	F=1057.9 P<0.001*
Phosphorus	21.85±0.51	13.59±02.53	16.90±0.68	19.30±0.92	F=60.30 P<0.001*
CA/ P ratio	2.07±0.05	1.93±0.22	1.69±0.63	1.76±0.09	F=18.89 P<0.001*

Similar superscripted letter denotes non-significant difference between groups

*Statistically significant, Parameters described as mean ±SD

F: One Way ANOVA Test

DISCUSSION

Initial carious lesions are termed WSLs. The development of these lesions occurs due to imbalance between demineralization and remineralization as a result of plaque accumulation on retentive tooth areas and habitual carbohydrate ingestion. Brackets positioned on teeth during fixed orthodontic mechanotherapy enhance plaque aggregation compared to smooth enamel surfaces that show lower caries incidence. White spot lesions can appear early, usually within a month which

represents the duration between two treatment visits.^(16,17)

In the present work, a significant rise in the demineralization values manifested by porosities on the enamel surface and a significant drop ($p < 0.001$) in the calcium and phosphorus levels and a significant difference in the Ca/P ratio was noticed adjacent to either esthetic brackets or CA attachments in comparison to the control group, these findings clarify how the orthodontic mechanotherapy could influence the enamel surface significantly. The lack

of any orthodontic treatment modality in the control group decreased the plaque aggregation which leads to reduced deleterious effect on the enamel surface. These results were in accordance with Akin M. et al. who revealed that the hazard of WSL formation is greater in orthodontic patients compared to others.⁽¹⁸⁾

Metal brackets are aesthetically inconvenient for a great number of patients, thus the need for esthetic appliances has drawn an increasing attention.⁽¹⁹⁾ There is a wide variety of esthetic orthodontic bracket materials existing in the market along with the new clear aligners, and information about which of them is accompanied by less bacterial adhesion, and subsequent enamel demineralization could strongly impact the treatment choice, particularly when bearing in mind the patient's poor hygiene.⁽²⁰⁾

Many studies compared the effect of esthetic ceramic brackets versus the metallic ones on enamel surface demineralization but studies comparing esthetic brackets and clear aligner regarding this point of interest are limited in literature. It is noteworthy that all other previous studies declaring the relation between clear aligners and WSLs didn't utilize ultrastructure investigation.

In the present study the ultrastructure scanning electron microscopic findings showed that the surface enamel demineralization and porosity associated with clear aligners were less than that associated with either polycrystalline or monocrystalline ceramic brackets. This result was confirmed by the EDX results which revealed significant reduction in the amount of calcium and phosphorous ions in both ceramic groups more than the CAs group.

Barcellos R. et al as well as Lim et al. reported that ceramic brackets have greater surface roughness than other brackets.^(21, 22) Regarding bacterial adhesion, surface roughness is the predominant controlling characteristic which leads to greater plaque retention. This may be a strong clarification of the greater enamel surface demineralization found

in ceramic brackets in the present study more than in clear aligners. Maltagliati L et al have confirmed that ceramic brackets showed the highest roughness as a honeycomb pattern was apparent.⁽¹⁹⁾

Arhun et al explained the greater enamel porosity and WSLs found with ceramic brackets at the adhesive–enamel interface by the presence of microleakage. They revealed that microleakage appear around ceramic brackets more than metal brackets.⁽²³⁾ Lindel et al confirmed these results, as they detected that enamel demineralization taking place with ceramic brackets is greater than that found with metallic ones.⁽²⁴⁾

Our results showed also that the polycrystalline ceramic group had deeper enamel porosities and significant mineral loss than both mono crystalline and CA groups, this may be attributed to the fact stated by Sarul M. et al who declared that monocrystalline brackets offer great smoothness of the surface accompanied by very high hardness and rounded edges which may favor bacterial detachment and cleaner tooth surface.⁽²⁵⁾

Moreover polycrystalline brackets are formed from aluminum oxide particles and binders, they undergo harsh manufacturing procedures as they are molded cut and burned. These manufacturing techniques may create pores, defects and microfractures which increase the surface roughness. enhance the plaque aggregation and prevent microbial detachment with subsequent greater acid production and greater enamel surface demineralization.^(26, 27)

On the other hand, other studies did not put the surface roughness or bracket design into consideration in dealing with ceramic brackets and they explained their point by the existence of aluminum oxide in ceramic brackets which has antibacterial effect on the surface⁽²⁸⁾

Although CAs offer a greater esthetic potential and a good chance for the patient to monitor his

oral hygiene, they still favor bacterial colonization to some extent. This was evident by the findings of the current study which showed the presence of some alteration, irregularities and porosities on the enamel surface and revealed the development of WSLs on the enamel surface accompanied by loss of the calcium and phosphorus content in CAs group more than in the control group but less than that in poly and monocrystalline groups.

The presence of demineralization areas may be explained by the Studies demonstrating that wearing aligners for 14 days lead to the development of abraded sites, microfractures and restricted calcified biofilm residues.⁽²⁹⁾ Low et al also noticed the formation of biofilm with a complicated composition with remarkable aggregation in recessed and sheltered parts of the appliance, like the attachment dimples.⁽³⁰⁾

The low grade enamel demineralization in comparison with esthetic brackets was in accordance with Chhibber A, who compared CAs with fixed appliances revealing that although the surface area of WSLs was found to be more in the CA group, there was greater amount of mineral loss detected in the fixed appliances. This finding was clarified with the obvious increase of the plaque amount located around the fixed appliances group and agrees with almost all the studies that illustrated their association.⁽³¹⁾

CONCLUSIONS

- Esthetic orthodontic appliances either fixed like the polycrystalline or monocrystalline ceramic brackets or removable like clear aligners can cause surface enamel demineralization (WSLs) and loss of mineral content but with varying degrees.
- Clear aligner therapy is recommended for patients with high risk of white spot lesion formation.

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