

## Assessment of Bracket Surface Morphology and Dimensional Change

### Abstract

**Objective:** The objective of this study was to compare the surface morphology and dimensional stability of the bracket slot at the onset of treatment and after 12 months of intraoral exposure. The study also compared the amount of calcium at the bracket base which indicates enamel loss among the three orthodontic brackets following debonding after 12 months of intraoral exposure. **Materials and Methods:** The sample consisted of 60 (0.022" MBT) canine brackets. They were divided into three groups: self-ligating, ceramic bracket with metal slot, and stainless steel (SS) brackets. The slot dimensions, micromorphologic characteristics of as-received and retrieved brackets were measured with a stereomicroscope and scanning electron microscope (SEM), respectively. The amount of calcium at the bracket base which indicates enamel damage was quantified using energy-dispersive X-ray spectrometry (EDX). **Results:** The results showed statistically significant alterations ( $P < 0.05$ ) in the right vertical dimension, internal tie wing width (cervical), right and left depth of the slot (Kruskal–Wallis test). Multiple comparison using Mann–Whitney test showed that ceramic brackets underwent ( $P < 0.05$ ) minimal alterations in the right vertical dimension, internal tie wing width (cervical), right and left depth of the slot (0.01 mm, -0.003 mm, 0.006 mm, -0.002 mm, respectively) when compared with the changes seen in SS and self-ligating brackets. SEM analysis revealed an increase in the surface roughness of ceramic with metal slot brackets and self-ligating bracket showed the least irregularity. The presence of calcium was noted on all evaluated brackets under EDX, but ceramic with metal slot brackets showed a significantly greater amount of enamel loss ( $P = 0.001$ ). **Conclusion:** Ceramic brackets were found to be dimensionally stable when compared to SS and self-ligating. Self-ligating bracket showed minimal surface irregularity. Ceramic with metal slot brackets showed a greater amount of enamel loss following debonding.

**Keywords:** Calcium, dimensional stability, enamel loss, orthodontic brackets, surface roughness

### Introduction

By the late 1970s, direct bonding of brackets had become an accepted clinical procedure in orthodontics. At present, orthodontic brackets are fabricated from several types of materials with varying degrees of roughness such as metal, ceramic, plastic, titanium, and composite. Degradation of orthodontic brackets during intraoral use has long been a concern of biomaterial science. It is considered that the oral medium and time can influence the physical-chemical properties of orthodontic brackets and archwires. *In vivo* aged orthodontic components show signs of degradation such as morphologic changes, surface alterations from corrosion, and wear and release of elements into the oral environment.<sup>[1]</sup> Amini *et al.*<sup>[2]</sup> found a significantly higher concentration of nickel in oral mucosa cells of patients wearing

fixed orthodontic appliances. Concerning biocompatibility, nickel is carcinogenic, mutagenic, and cytotoxic. According to Anuradha *et al.*,<sup>[3]</sup> titanium sputter coated nickel titanium (NiTi) archwires seem to be promising for nickel sensitive patients. It showed a reduced surface roughness, friction coefficient, good adhesion and minimal hardness, and elastic modulus variations in artificial saliva over a given time period.

Surface alterations in orthodontic devices might compromise the appliances esthetics, increase microbial adhesion, and modify bracket wire activations such as torque expression and influence the magnitude of friction between the bracket and the wire.<sup>[4]</sup> Oral cavity differs from the *in vitro* media in the presence of complex oral microflora and their byproducts which cannot be simulated with the currently available *in vitro* research methodologies.<sup>[5]</sup> As far as aging is concerned, many studies have

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focused on the ionic release into the oral cavity, but the physical alterations that orthodontic brackets undergo *in vivo* and their impact on clinical performance are unknown.

Bracket debonding procedure leaving more residual debris on the bracket base is undesirable because of the increased probability of tooth enamel damage.<sup>[6]</sup> There are several important differences between *in vitro* and *in vivo* studies dealing with modes of bracket failure. The *in vivo* debonding load is a combination of shear, tension, and torsion force, whereas *in vitro* studies are conducted by means of single tests (shear, tensile, or torsion). Furthermore, the complex oral environment involves continually changing temperature, stresses, humidity, acidity, and variability in the amount and composition of plaque. These conditions cannot be reproduced in the laboratory; therefore, *in vitro* studies could not be highly relevant from the standpoint of scientific and clinical evidence.

Efficient mechanotherapy is sustained by the use of most suitable bracket for orthodontic patients. As there are different types of brackets available for the same prescription, it is very important to evaluate their properties with intraoral exposure and to quantify the amount of calcium present at the bracket base after debonding, thereby understanding the loss of enamel thickness which occurs iatrogenically. Therefore, the aim of the present study was to compare the dimensional stability and surface morphology of the bracket slot among three different orthodontic brackets, i.e., self-ligating (Smart clip 3M Unitek), ceramic bracket with metal slot (Clarity 3M Unitek), and stainless steel (SS) brackets (Gemini 3M Unitek) at the onset of treatment and after 12 months of intraoral exposure. The present study also assessed the enamel loss by quantifying and comparing the amount of

calcium at the bracket base among these three brackets following debonding after 12 months of intraoral exposure.

### Materials and Methods

The study was conducted on patients who reported to the Department of Orthodontics, Amrita School of Dentistry, Kochi, for undergoing orthodontic treatment. Ethical approval for the study was obtained from the concerned University Scientific Committee. The sample consisted of 60 (0.022” MBT) maxillary canine brackets. They were divided into three groups: Self-ligating (Smart clip 3M Unitek), ceramic bracket with metal slot (Clarity 3M Unitek), and SS brackets (Gemini 3M Unitek). These groups were further divided into two: brackets as received from the manufacturer and brackets retrieved after 12 months of intraoral exposure with a total of 10 brackets in each group [Table 1]. Brackets were retrieved after 12 months of intraoral exposure from thirty patients (ten for each group) undergoing orthodontic treatment with a mean age of 20 years.

#### Procedure for bonding the brackets

The labial enamel surfaces of the teeth were cleaned and polished with a slow speed handpiece using slurry made of nonfluoride pumice and water. They were then rinsed and dried with a moisture free air spray.

Subsequently, the enamel was etched with 35% orthophosphoric acid gel for 30 s, rinsed with water, air sprayed for 30 s, and then dried until the etched enamel surface exhibited a frosty white appearance. The brackets were bonded on the teeth surfaces using an adhesive system (Transbond XT light cure adhesive primer and Transbond XT adhesive resin, 3M Unitek) applied in strict accordance with the manufacturer’s instructions.

**Table 1: Sample and groups**

Number of brackets <i>n</i> = 60					
STAINLESS STEEL (Gemini 3M Unitek) <i>n</i> = 20		SELF LIGATING (Smart clip 3M Unitek) <i>n</i> = 20		CERAMIC WITH METAL SLOT (Clarity 3M Unitek) <i>n</i> = 20	
GROUP A1	GROUP A	GROUP B1	GROUP B	GROUP C1	GROUP C
CONTROL	TEST	CONTROL	TEST	CONTROL	TEST
<i>n</i> = 10	<i>n</i> = 10	<i>n</i> = 10	<i>n</i> = 10	<i>n</i> = 10	<i>n</i> = 10
As received from manufacturer	Subjected to oral environment	As received from manufacturer	Subjected to oral environment	As received from manufacturer	Subjected to oral environment
Lost to follow up ( <i>n</i> = 0)					
Analysed ( <i>n</i> = 0)					
Variables measured					
Slot sizes left and right vertical dimensions					
Internal tie wing width cervical and occlusal					
Depth of the slot right and left					
Surface roughness of the slot					
Presence of calcium at the bracket base					

The brackets were placed on the tooth surface, adjusted to their final position, and pressed firmly in place. The excess resin was then removed from the periphery of the bracket base using a dental probe. Light curing was performed for 20 s (10 s on the mesial side and 10 s on the distal side) using a light-emitting diode unit light. The sequence of wires used for all the patients throughout the treatment was NiTi 0.016 inch, 0.016 × 0.022 inch, 0.017 × 0.025 inch, 0.019 × 0.025 inch, and SS 0.019 × 0.025 inch. Wires were ligated with elastomeric ligatures.

### Bracket debonding

The terminal wire used in all the three groups of brackets before debonding was 0.019 × 0.025 inch SS as it exhibits minimal slot-archwire “play.” After 12 months of intraoral exposure, all the thirty right canine brackets (SS, self-ligating, and ceramic with metal slot), ten each were debonded with bracket removing plier (3M Unitek) with force applied only to the bracket base. At the time of debonding to avoid any distortion of the bracket slot, a full-size sectional arch wire was left in place. The retrieved brackets were rinsed with distilled water to remove any loosely attached debris and were kept in self-sealed sterilizing packs until analysis.

### Stereomicroscopic assessment of bracket slot dimensions

The slot sizes (left and right vertical dimension), internal tie wing width (cervical and occlusal), and the right and left depth of the slot [Figures 1 and 2] of all the sixty brackets, i.e., thirty as-received and thirty retrieved brackets, were measured with a stereomicroscope (Leica MZ7.5 Ergo Trinocular Zoom). All the brackets were scanned under ×20 magnification.

### Scanning electron microscope analysis of bracket slot surface roughness

The micromorphologic characteristics of slot surfaces of 18 randomly selected brackets, with three brackets

of each group were analyzed with a scanning electron microscope (SEM) (JSM – 6490 LA; Jeol, Tokyo, Japan) after 12 months of intraoral exposure and were compared to their controls. The SEM was operated at 15 kV accelerating voltage and low vacuum chamber pressure where imaging of nonconductive specimens can be done without the need for conductive coating with a working distance of 9 mm. The middle portion of the base of the bracket slot surface was scanned under ×500 magnification which was then progressively inspected in detail at higher magnification of ×1000 to detect the presence of surface roughness. The surface characteristics were determined on the basis of a visual evaluation of the surface irregularity.

### Energy-dispersive X-ray spectrometry for assessing enamel damage

The amount of calcium at the bracket base which indicated the damage of enamel was quantified in terms of percentage *ex vivo* from the debonded brackets using energy-dispersive X-ray spectrometry (EDX) mean area scan analysis (JSM 6490 LA Jeol) (accelerating voltage 15 Kv, at magnification of ×3000). EDX analysis was performed on the entire surface of the bracket base.

## Results

### Bracket slot dimensions

Wilcoxon signed-rank test was used to compare the as-received and retrieved slot dimensions of the three different orthodontic brackets. When the slot dimensions of as-received brackets and retrieved brackets were compared, Group A (retrieved SS brackets) showed a significant reduction in the width of the internal tie wing on the cervical area (Group A1 = 1.57, Group A = 1.53)  $P = 0.02$ , vertical dimension on the right side (Group A1 = 0.58, Group A = 0.55)  $P = 0.00$ , and an increase in the depth of the slot on the right side (Group A1 = 0.83, Group A = 0.91)  $P = 0.00$  [Table 2]; Group C (retrieved ceramic with metal slot brackets) showed a significant reduction in the vertical dimension on the right (Group C1 = 0.68, Group C = 0.66)  $P = 0.02$  and left side of the slot (Group C1 = 0.69, Group C = 0.67)  $P = 0.02$ , width of the

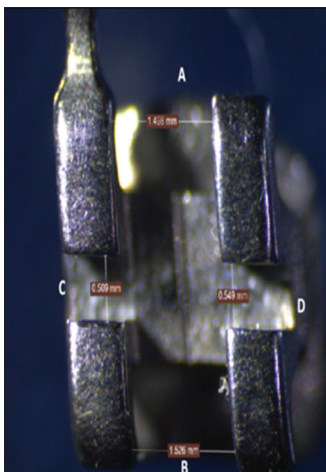


Figure 1: Measurements made on bracket slot using stereomicroscope; A - Internal tie wing width (cervical), B - Internal tie wing width (occlusal), C - Right vertical dimension, D - Left vertical dimension

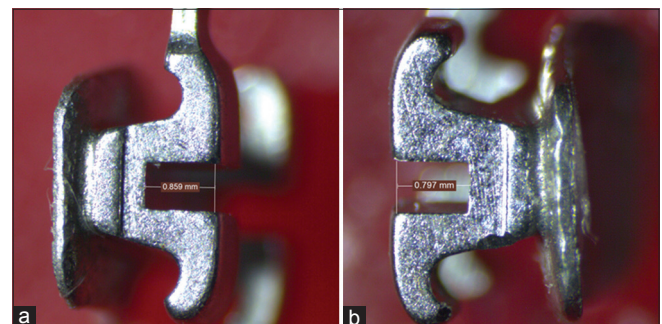


Figure 2: Measurements made on bracket slot using stereomicroscope; (a) Depth of the right slot; (b) depth of the left slot

internal tie wing on the occlusal area (Group C1 = 1.67, Group C = 1.61)  $P = 0.02$  [Table 3], whereas Group B (retrieved self-ligating bracket) did not show any statistically significant change after 12 months of intraoral exposure [Table 4].

The difference between the slot dimensions of thirty as-received brackets (Group A1, Group B1, Group C1) and thirty retrieved brackets (Group A, Group B, Group C) was calculated. Kruskal–Wallis test was used to compare the difference in slot dimensions of the retrieved brackets (Group A, Group B, Group C) with each other. The results showed a significant difference ( $P < 0.01$ ) in the vertical dimension on the right side, internal tie wing width on the cervical area, right and left depth of the slot between the three retrieved brackets (Group A, Group B, Group C) [Table 5]. Mann–Whitney test was then performed

**Table 2: Comparison of slot dimensions of as-received and retrieved stainless steel brackets**

Measurements (mm)	Stainless steel	Mean	SD	P
Right vertical dimension	Group A1	0.583	0.014	0.007
	Group A	0.554	0.013	
Left vertical dimension	Group A1	0.562	0.010	0.064
	Group A	0.522	0.093	
Internal tie wing width (cervical)	Group A1	1.574	0.021	0.021
	Group A	1.536	0.038	
Internal tie wing width (occlusal)	Group A1	1.568	0.048	0.059
	Group A	1.518	0.046	
Depth of the slot (right)	Group A1	0.834	0.022	0.005
	Group A	0.911	0.033	
Depth of the slot (left)	Group A1	0.785	0.030	0.396
	Group A	0.778	0.015	

Group A1: As-received stainless steel bracket; Group A: Retrieved stainless steel bracket; SD: Standard deviation

**Table 3: Comparison of as-received and retrieved ceramic with metal slot brackets slot dimensions**

Measurements (mm)	Ceramic with metal slot	Mean	SD	P
Right vertical dimension	Group C1	0.683	0.007	0.024
	Group C	0.665	0.026	
Left vertical dimension	Group C1	0.696	0.011	0.024
	Group C	0.679	0.009	
Internal tie wing width (cervical)	Group C1	1.314	0.013	0.073
	Group C	1.317	0.111	
Internal tie wing width (occlusal)	Group C1	1.675	0.017	0.028
	Group C	1.618	0.114	
Depth of the slot (right)	Group C1	0.978	0.015	0.369
	Group C	0.972	0.017	
Depth of the slot (left)	Group C1	0.883	0.013	0.888
	Group C	0.885	0.018	

Group C1: As-received ceramic with metal slot bracket; Group C: Retrieved ceramic with metal slot bracket; SD: Standard deviation

to compare pairs of means that are different. Table 6 shows the results of *post hoc* Mann–Whitney test. A significant difference was observed between Group A (retrieved SS brackets) and Group B (retrieved self-ligating brackets) in the right vertical dimension (95% confidence interval [CI]: Group A: -0.03, 0.20; Group B: -0.009, 0.03) ( $P = 0.007$ ), internal tie wing width on the cervical area (95% CI: Group A: 0.00, 0.06; Group B: 0.04, 0.23) ( $P = 0.001$ ), depth of the slot on the right side (95% CI: Group A: -0.10, -0.04; Group B: -0.00, 0.10) ( $P = 0.001$ ), depth of the slot on the left side (95% CI: Group A: -0.01, 0.02; Group B: 0.05, 0.17) ( $P = 0.002$ ). A significant difference between Group A (retrieved SS) and Group C (retrieved ceramic with metal slot bracket) was detected in the width of the internal tie wing on the cervical area (95% CI: Group A: 0.00, 0.06; Group C: -0.07, 0.07) ( $P = 0.007$ ), depth of the slot on the right side (95% CI: Group A: 0.10, -0.04; Group C: -0.01, 0.02) ( $P = 0.001$ ). Depth of the slot on the left side showed a significant difference between Group B (retrieved self-ligating brackets) and Group C (retrieved ceramic with metal slot brackets) (95% CI: Group B: 0.05, 0.17; Group C: -0.01, 0.01) ( $P = 0.001$ ) [Table 6].

No significant differences were observed in the vertical dimension on the right side ( $P = 0.35$ ), width of the internal tie wing on the cervical area ( $P = 0.10$ ), and depth of the slot on the right side ( $P = 0.07$ ) between Group B (retrieved self-ligating brackets) and Group C (retrieved ceramic with metal slot brackets). Vertical dimension on the right side ( $P = 0.05$ ) and depth of the slot on the left side ( $P = 0.63$ ) between Group A (retrieved SS brackets) and Group C (retrieved ceramic with metal slot brackets) was found to be insignificant.

In the results of this study, Group A (retrieved SS brackets) showed a significant reduction ( $P = 0.001$ ) in the depth of the slot on the right side by -0.07 mm when compared to Group B (retrieved self-ligating brackets) and Group C (retrieved ceramic with metal slot brackets) (0.04 mm and 0.006 mm, respectively). Group A (retrieved SS brackets) also showed a significant ( $P = 0.007$ ) increase in the vertical dimension on the right side by 0.08 mm when compared to Group B (retrieved self-ligating brackets) (0.01 mm). Depth of the slot on the left side was found to be statistically increased ( $P < 0.05$ ) in Group B (retrieved self-ligating brackets) by 0.11 mm when compared to Group A (retrieved SS brackets) (0.007 mm) and Group C (retrieved ceramic with metal slot brackets) (-0.002 mm) brackets. Group B (retrieved self-ligating brackets) also showed a significant ( $P < 0.05$ ) increase in the width of the internal tie wing by 0.14 mm when compared to Group A (retrieved SS brackets) (0.03 mm). Statistically, the difference in ceramic with metal slot brackets showed only a minimal change in the vertical dimension on the right side, internal tie wing on the cervical aspect, depth of the slot on the right and left side (0.01 mm, -0.003 mm, 0.006

mm, -0.002 mm respectively) when compared with the changes of Group A and Group B brackets [Tables 5 and 6].

**Surface roughness**

SEM analysis of as-received and retrieved brackets demonstrated that time had a gradual influence on the slot surface of the brackets which could be due to the accumulation of biofilm. The presence of pits, grooves, and deformations of varying extension could also be observed on the bracket slot surfaces.

When all the three as-received brackets were compared, Group C1 (ceramic brackets) [Figure 3a and c] showed a relatively smooth surface, whereas the Group A1 (SS brackets) [Figure 4a

and c] and Group B1 (self-ligating brackets) [Figure 5a and c] showed pits and grooves on the slot surface.

When all the three retrieved brackets were compared Group C (retrieved ceramic with metal slot brackets) showed an increase in the slot surface roughness with the presence of crevices, cracks, and gaps [Figure 3b and d], Group A (retrieved stainless steel bracket) [Figure 4b and d] showed few irregularities but Group B (retrieved self-ligating bracket) showed the least irregularity [Figure 5b and d].

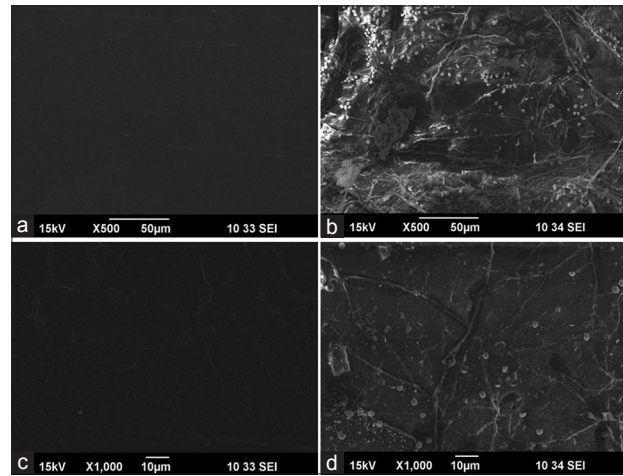
**Presence of calcium at the bracket base**

Kruskal–Wallis test was used to determine the amount of calcium at the bracket base among the three orthodontic

**Table 4: Comparison of as-received and retrieved self-ligating bracket slot dimensions**

Measurements (mm)	Group B (self-ligating)	Mean	SD	P
Right vertical dimension	Group B1	0.620	0.018	0.250
	Group B	0.608	0.027	
Left vertical dimension	Group B1	0.608	0.015	0.134
	Group B	0.545	0.158	
Internal tie wing width (cervical)	Group B1	1.099	0.026	0.008
	Group B	0.958	0.137	
Internal tie wing width (occlusal)	Group B1	1.075	0.024	0.207
	Group B	0.995	0.161	
Depth of the slot (right)	Group B1	0.808	0.016	0.092
	Group B	0.761	0.067	
Depth of the slot (left)	Group B1	0.791	0.028	0.070
	Group B	0.672	0.069	

Group B1: As-received self-ligating bracket; Group B: Retrieved self-ligating bracket; SD: Standard deviation



**Figure 3: (a and b) Scanning electron microscope surface images of as-received and retrieved ceramic with metal slot brackets at ×500; (c and d) scanning electron microscope surface images of as-received and retrieved ceramic with metal slot brackets at ×1000**

**Table 5: Comparison between the difference in slot dimensions among the three retrieved brackets**

Measurements (mm)	Retrieved brackets	Mean	SD	95% CI for mean		P
				Lower bound	Upper bound	
Right vertical dimension difference	Group A (stainless steel)	0.08	0.17	-0.03	0.20	0.018*
	Group B (self-ligating)	0.01	0.03	-0.009	0.03	
	Group C (ceramic with metal slot)	0.01	0.02	0.00	0.03	
Left vertical dimension difference	Group A (stainless steel)	0.04	0.09	-0.02	0.10	0.971
	Group B (self-ligating)	0.06	0.16	-0.05	0.17	
	Group C (ceramic with metal slot)	0.01	0.01	0.00	0.02	
Internal tie wing width (cervical) difference	Group A (stainless steel)	0.03	0.04	0.00	0.06	0.001*
	Group B (self-ligating)	0.14	0.13	0.04	0.23	
	Group C (ceramic with metal slot)	-0.003	0.10	-0.07	0.07	
Internal tie wing width (occlusal) difference	Group A (stainless steel)	0.05	0.06	0.00	0.09	0.952
	Group B (self-ligating)	0.08	0.14	-0.02	0.18	
	Group C (ceramic with metal slot)	0.05	0.10	-0.01	0.13	
Depth of the slot (right) difference	Group A (stainless steel)	-0.07	0.04	-0.10	-0.04	0.001*
	Group B (self-ligating)	0.04	0.07	-0	0.10	
	Group C (ceramic with metal slot)	0.006	0.02	-0.01	0.02	
Depth of the slot (left) difference	Group A (stainless steel)	0.00	0.03	-0.01	0.02	0.001*
	Group B (self-ligating)	0.11	0.08	0.05	0.17	
	Group C (ceramic)	-0.002	0.02	-0.01	0.01	

\*Significant at 5% level. CI: Confidence interval; SD: Standard deviation

brackets after 12 months of intraoral use. The result of EDX analysis shows a statistically significant difference

**Table 6: Multiple comparison using *post hoc* tests - Mann-Whitney**

Slot dimensions	Multiple comparison of the changes in the retrieved brackets	P
Right vertical dimension	Group A (retrieved stainless steel) - Group B (retrieved self-ligating)	0.007*
	Group A (retrieved stainless steel) - Group C (retrieved ceramic with metal slot)	0.052
	Group B (retrieved self-ligating) - Group C (retrieved ceramic with metal slot)	0.353
Internal tie wing width (cervical)	Group B (retrieved self-ligating) - Group A (retrieved stainless steel)	0.001*
	Group C (retrieved ceramic with metal slot) - Group A (retrieved stainless steel)	0.007*
	Group B (retrieved self-ligating) - ceramic with metal slot	0.105
Depth of the slot (right)	Group B (retrieved self-ligating) - Group A (retrieved stainless steel)	0.001*
	Group B (retrieved self-ligating) - Group C (retrieved ceramic with metal slot)	0.075
	Group A (retrieved stainless steel) - Group C (retrieved ceramic with metal slot)	0.001*
Depth of the slot (left)	Group B (retrieved self-ligating) - Group C (retrieved ceramic with metal slot)	0.001*
	Group A (retrieved stainless steel) - Group C (retrieved ceramic with metal slot)	0.631
	Group B (retrieved self-ligating) - Group A (retrieved stainless steel)	0.002*

\*Significant at 5% level

between the amount of calcium between Group B and Group C (self-ligating and ceramic with metal slot brackets) ( $P < 0.05$ ) and between Group A and Group C (SS brackets and ceramic with metal slot brackets) with the ceramic bracket base ( $P < 0.05$ ) showing the highest amount of calcium followed by the SS bracket base. However, there is no statistically significant difference between the presence of calcium at the self-ligating and SS bracket bases [Table 7].

### Discussion

Retrieval analysis has gained special interest in biomaterials research since the *in vivo* environment cannot be adequately simulated under current *in vitro* research methodological approaches. Variations in temperature and pH as registered intraorally may cause the biodegradation of these materials, changing some of their properties which may compromise their clinical performance.<sup>[7]</sup> The combined action of these biological factors can significantly alter the integrity of the orthodontic bracket surface. Alteration in the integrity of the brackets can be seen in the form of intraslot wear, deformation, and roughness.<sup>[5]</sup>

The surface roughness of dental material is critical since it determines the contact area and influences the corrosion behavior and biocompatibility of the material. The orthodontic brackets should have the proper hardness and strength to withstand an accurate force from the archwire to the teeth. In addition, they should have a smooth slot surface to reduce the frictional resistance. Unfortunately, there is little information in literature regarding the changes in the slot dimensions and surface roughness of the brackets before and after clinical use. In this study, these factors were evaluated from the change in the morphology of each bracket before and after 12 months of intraoral exposure. The present study also evaluated the amount of enamel loss

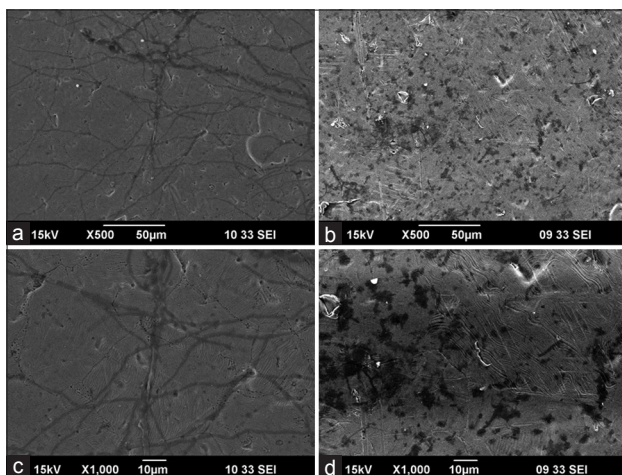


Figure 4: (a and b) Scanning electron microscope surface images of as-received and retrieved steel brackets at  $\times 500$ ; (c and d) scanning electron microscope surface images of as-received and retrieved steel brackets at  $\times 1000$

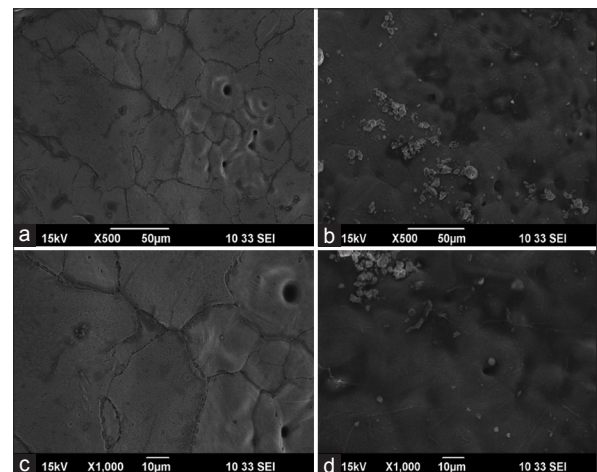


Figure 5: (a and b) Scanning electron microscope surface images of as-received and retrieved self-ligating brackets at  $\times 500$ ; (c and d) scanning electron microscope surface images of as-received and retrieved self-ligating brackets at  $\times 1000$

**Table 7: Mean amount of calcium present between the three bracket bases**

Brackets	Mean amount of Ca (%)	SD	P
Stainless steel (Group A)	1.44	0.53	1.00
Self-ligating (Group B)	1.42	0.74	0*
Ceramic with metal slot (Group C)	4.00	0.97	0.001*

\*Significant at 5% level. SD: Standard deviation; Ca: Calcium

which is determined by the presence of calcium present at the bracket base following debonding.

The brackets used in this study were MBT 0.022” slot SS, self-ligating, ceramic with metal slot. These brackets were chosen as they exhibit different compositions and there are no studies in literature comparing the physical changes of these brackets after 12 months of intraoral exposure.

Generally, extraction is indicated during orthodontic treatment; canine retraction through sliding mechanics is applied to close the resultant space; for this reason, canine brackets were selected for the present study.

All brackets were conventionally bonded using the “etch and bond technique.” After 12 months of intraoral exposure, all canine brackets were debonded with bracket removing plier (3M Unitek, Monrovia, Calif). According to Coley-Smith and Rock, bracket removing pliers when used, the archwire should be left in place since this reduces the number of distortions of the bracket slot and the use of bracket removing pliers after removal of the archwire produced significantly greater numbers of distorted brackets.<sup>[8]</sup> In a photoelastic stress analysis, it was found that forces applied to the outer wings of the bracket transferred the least amount of stress to the enamel, whereas the force applied to the base of the bracket and to the adhesive zone created stress concentration regions in the enamel that would cause separation at the adhesive-enamel interface.<sup>[9]</sup> However, Brosh *et al.*<sup>[10]</sup> did not find any significant difference in the calcium scores with the pliers applied either at the base of the bracket or at the tie wing.

In this study, to eliminate any possible influence of the method of debonding on the values of the measurements of the bracket slot, a full-size sectional archwire was left in place at the time of debonding and debonding was accomplished by carefully applying force only to the bracket base thus preserving the area of interest.

Stereomicroscopic analysis of as-received and retrieved brackets suggested a significant change in the slot dimensions of ceramic with metal slot bracket and SS, whereas the retrieved self-ligating brackets did not show any significant difference in the slot dimensions when compared with their as-received counterpart.

When the differences in slot dimensions of the three retrieved brackets (Group A, Group B, Group C) were compared with each other, a statistically significant alteration in the vertical dimension on the right side ( $P = 0.01$ ), width of the internal tie wing on the cervical aspect ( $P = 0.01$ ), depth of the slot on the right ( $P \leq 0.01$ ) and left side ( $P \leq 0.01$ ) was observed.

In this study, all the three brackets showed changes in the slot dimensions after 12 months of intraoral exposure, but Group C (retrieved ceramic with metal slot brackets) exhibited minimal alterations in the slot dimensions when compared to Group A (retrieved SS brackets) and Group B (retrieved self-ligating brackets) [Tables 5 and 6]. According to Eliades *et al.*, ceramic brackets are quite stable, proper dimensional stability of ceramic brackets may be due to the brittleness of the material, which does not allow significant deformation before fracturing.<sup>[11]</sup> Self-ligating brackets and SS brackets are similar in their compositions. In this study, the vertical dimension on the right side of Group A (retrieved SS brackets) increased by 0.08 mm which is in agreement with the study done by Regis *et al.*<sup>[4]</sup> Group B (retrieved self-ligating brackets) showed a significant increase in the width of the internal tie wing by 0.14 mm when compared to Group A (retrieved SS brackets). Depth of the slot on the left side was found to be statistically increased ( $P < 0.05$ ) in Group B (retrieved self-ligating brackets) by 0.11 mm when compared to Group A (retrieved SS brackets) (0.007 mm) and Group C (retrieved ceramic with metal slot brackets) (-0.002 mm) brackets. The changes in these bracket slot dimensions can be related to the intraslot wear or deformation due to the dental sliding mechanics, torque, and progressive increase in the thickness of the wires used in the brackets.<sup>[5,12,13]</sup> A significant reduction in the depth of the slot on the right side by - 0.07 mm was observed in Group A (retrieved SS brackets). A study done by Dos Santos *et al.*<sup>[14]</sup> demonstrated that time had a gradual influence on the accumulation of biofilm, debris, and food remainders on the surface and slots of the brackets. A reduction in slot dimension observed in this study could be related to the fact that when a biomaterial is exposed to a biological system, a noncellular acquired biofilm is rapidly organized on the material surface by spontaneous adsorption of extracellular macromolecules composed of glycoproteins and proteoglycans which later calcifies and alters the structure of the biomaterial.<sup>[5]</sup> A study done by Eliades *et al.* stated that biological factors can significantly alter the integrity of orthodontic brackets, especially metallic brackets.<sup>[5]</sup> In the present study, this could be the reason for significantly greater alteration in the slot dimensions of Group A (retrieved SS) and Group B (retrieved self-ligating brackets).

Surface profilometry is the most commonly used method to measure the surface roughness of orthodontic material, but

the disadvantage is that it can induce sample damage and is difficult to use for overall surface roughness measurement due to its use of a single line in a preselected area as mentioned by Lee *et al.*<sup>[15]</sup> To overcome this disadvantage of surface profilometry, surface roughness in this study was measured using SEM which has a large depth of field yielding a characteristic three dimensional appearance useful for understanding the surface structure of the sample.

SEM analysis showed that all the as-received brackets from the manufacturer presented some surface irregularities, which according to Pithon *et al.*<sup>[12]</sup> and Gkantidis *et al.*<sup>[16]</sup> would compromise the ideal fitting of the orthodontic wire within the slot walls.

In this study, Group C (retrieved ceramic with metal slot) brackets showed greater amount of surface roughness [Figure 3b and d] and Group B (retrieved self-ligating brackets) presented minimal surface irregularity [Figure 5b and d] after 12 months of intraoral exposure. According to Loftus *et al.*,<sup>[17]</sup> ceramic brackets with SS slots have superior frictional qualities compared with those of conventional ceramic but not as efficient as metal brackets.

This could be because of several factors such as:

- The friction in Clarity brackets increases in the wet state as observed by Thorstenson and Kusy<sup>[18]</sup>
- The metal inserts of the brackets neither have a constant width along the slot nor extend to the top of it as observed by Kusy and Whitley.<sup>[19]</sup>

The relatively smoother surface of Group B (retrieved self-ligating bracket) in this study can be attributed to the fact that self-ligating brackets used in this study are characterized by the presence of a fourth mobile wall that converts the slot into a tube, allowing the wire to freely move inside the bracket slot; thus, reducing the contact area between the bracket and the wire which in turn will reduce the surface roughness. The results of this study with regard to surface roughness of self-ligating brackets is in accordance with Shivapuja and Berger,<sup>[20]</sup> who stated that self-ligating brackets generated less friction than conventional brackets which could be due to the smooth slot surface of the self-ligating brackets.

The study showed that clinical use caused changes in the surface of the brackets as seen in scanning electron microscopic images. According to Choi *et al.*,<sup>[21]</sup> the changes in the surface roughness of bracket slot can be due to corrosion from the saliva, mouth washing solution, or galvanic corrosion between two materials or due to the friction by the sliding movement of the archwire over the bracket slots. Surface roughness also arises from the presence of grove, gaps, and crevices and the deposition of debris during their intraoral use.

The study also confirms the presence of precipitated biofilm on retrieved brackets, which is seen as areas of

dark surface in SEM analysis.<sup>[14]</sup> This can alter the structure and surface integrity of the biomaterial.

According to Amini *et al.*,<sup>[22]</sup> increased surface roughness can increase frictional forces because it enhances the contact area between the bracket and the wire. This can, in turn reduce the orthodontic force by 50% or more thereby lowering the quality of orthodontic treatment.

Quantitative analysis of calcium present at the bracket base was done using EDX. The same canine brackets which were used to evaluate the slot morphology were used to determine the amount of enamel loss.

Enamel is composed of 95% inorganic component which is mainly calcium phosphate. Since none of the bonding materials used contained calcium, the presence of this element could only be attributed to enamel loss.<sup>[6]</sup>

EDX analysis showed a significant increase in the amount of calcium present at the ceramic with metal slot bracket base followed by the SS and self-ligating bracket bases. Apart from calcium, EDX analysis also showed the presence of oxygen, carbon, nitrogen, silicon, and phosphorous. Carbon should be attributed to surface contamination rather than an elemental component.<sup>[16]</sup>

Greater amount of calcium at the ceramic bracket base can be related to the fact that the ceramic brackets have increased bond strength. Odegaard and Segner<sup>[23]</sup> reported higher incidence of enamel damage after debonding ceramic bracket when compared to the metal brackets. The bond failure for the ceramic bracket occurred predominantly in the enamel/adhesive interface and the failure site for the metal bracket was mainly in the bracket/adhesive interface. In a study carried out by Bishara *et al.*,<sup>[24]</sup> the bond strengths of metallic brackets (Victory Series) were less than the ceramic brackets with mechanical retention (Clarity) which suggests a greater risk for enamel damage for ceramic bracket debonding. Enamel fracture during debonding is related to the high bond strength of ceramic brackets and sudden impact loading. A study conducted by Ciocan *et al.*<sup>[25]</sup> reported that the potential reason for greater amount of enamel loss with ceramic bracket debonding could be due the ceramic mesh which has a greater adhesion value than the bracket with metal mesh and the need for special debonding procedures as recommended by the manufacturer.

Many *in vitro* studies have shown that friction increases with increased roughness of the wire and bracket surface; however, they have mainly focused on the mechanical properties, not the changes resulting from intraoral exposure. This study determined the physical changes that occur in orthodontic brackets after intraoral exposure. The results of which suggest that there is a significant difference in the physical properties of orthodontic brackets before and after intraoral exposure with a progressive increase in surface alteration from 0 to 12 months of



intraoral exposure, so friction must be very well taken into consideration in treatment durations that may last for about 24–36 months which could compromise the clinical performance of the appliance.

In this study, ceramic brackets were found to cause a greater risk for enamel damage, which according to Ghafari *et al.*<sup>[26]</sup> can be prevented by avoiding sudden impact loading or stress concentration within the enamel using proper debonding techniques, avoiding bonding of ceramic brackets on structurally damaged teeth, adding a metal mesh at the base of the bracket, reducing the base area of the bracket, using weaker resins appropriate debonding procedures has to be undertaken, and the cases to be treated with ceramic brackets must be selected with caution.

Further studies should be conducted using a disclosing medium (GUM Red-cote, Chicago, USA) to verify whether fractured enamel surfaces are still visible after the cleanup and polishing procedure and also to investigate the influence of saliva in the remineralization of these lesions in a long-term follow-up.

## Conclusion

The present study on evaluating the effects of orthodontic treatment on the physical properties of three different types of brackets, namely, SS, self-ligating, ceramics with metal slot revealed the following:

- When the differences in slot dimensions of the three retrieved brackets (Group A, Group B, Group C) were compared with each other, all of them underwent significant alterations, but Group C (retrieved ceramic with metal slot brackets) exhibited significantly minimal alterations in the slot dimensions when compared to Group A (retrieved SS brackets) and Group B (retrieved self-ligating brackets)
- With regard to surface roughness, Group B (retrieved self-ligating brackets) exhibited least surface irregularity of three while Group C (retrieved ceramic with metal slot brackets) demonstrated greater surface roughness
- Thus, the study reveals that there is a significant difference in the physical properties of orthodontic brackets before and after intraoral exposure with a progressive increase in surface alteration from 0 to 12 months of intraoral exposure
- With regard to the calcium present at the bracket base, the result shows that debonding of all the three brackets lead to enamel loss, but ceramic with metal slot brackets showed a greater amount of enamel loss.

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## Conflicts of interest

There are no conflicts of interest.

## References

1. House K, Sernetz F, Dymock D, Sandy JR, Ireland AJ. Corrosion of orthodontic appliances – Should we care? *Am J Orthod Dentofacial Orthop* 2008;133:584-92.
2. Amini F, Borzabadi Farahani A, Jafari A, Rabbani M. *In vivo* study of metal content of oral mucosa cells in patients with and without fixed orthodontic appliances. *Orthod Craniofac Res* 2008;11:51-6.
3. Anuradha P, Varma NK, Balakrishnan A. Reliability performance of titanium sputter coated Ni-Ti arch wires: Mechanical performance and nickel release evaluation. *Biomed Mater Eng* 2015;26:67-77.
4. Regis S Jr., Soares P, Camargo ES, Guariza Filho O, Tanaka O, Maruo H. Biodegradation of orthodontic metallic brackets and associated implications for friction. *Am J Orthod Dentofacial Orthop* 2011;140:501-9.
5. Eliades T, Bourauel C. Intraoral aging of orthodontic materials: The picture we miss and its clinical relevance. *Am J Orthod Dentofacial Orthop* 2005;127:403-12.
6. Zanarini M, Gracco A, Lattuca M, Marchionni S, Gatto MR, Bonetti GA. Bracket base remnants after orthodontic debonding. *Angle Orthod* 2013;83:885-91.
7. Mendes Bde A, Neto Ferreira RA, Pithon MM, Horta MC, Oliveira DD. Physical and chemical properties of orthodontic brackets after 12 and 24 months: *In situ* study. *J Appl Oral Sci* 2014;22:194-203.
8. Coley-Smith A, Rock WP. Distortion of metallic orthodontic brackets after clinical use and debond by two methods. *Br J Orthod* 1999;26:135-9.
9. Bennett CG, Shen C, Waldron JM. The effects of debonding on the enamel surface. *J Clin Orthod* 1984;18:330-4.
10. Brosh T, Kaufman A, Balabanovsky A, Vardimon AD. *In vivo* debonding strength and enamel damage in two orthodontic debonding methods. *J Biomech* 2005;38:1107-13.
11. Eliades T, Eliades G, Brantley WA. Orthodontic brackets. In: Brantley WA, Eliades T, editors. *Orthodontic Materials: Scientific and Clinical Aspects*. New York: Thieme; 2001. p. 143-72.
12. Pithon MM, Santos Fonseca Figueiredo D, Oliveira DD, Dos Santos RL. Evaluation of physical properties of esthetic brackets after clinical use; study *in situ*. *J World Fed Orthod* 2013;2:127-32.
13. Gioka C, Eliades T. Materials-induced variation in the torque expression of preadjusted appliances. *Am J Orthod Dentofacial Orthop* 2004;125:323-8.
14. Dos Santos AA, Pithon MM, Carlo FG, Carlo HL, de Lima BA, Dos Passos TA, *et al.* Effect of time and pH on physical-chemical properties of orthodontic brackets and wires. *Angle Orthod* 2015;85:298-304.
15. Lee GJ, Park KH, Park YG, Park HK. A quantitative AFM analysis of nano-scale surface roughness in various orthodontic brackets. *Micron* 2010;41:775-82.
16. Gkantidis N, Zinelis S, Karamolegkou M, Eliades T, Topouzelis N. Comparative assessment of clinical performance of esthetic bracket materials. *Angle Orthod* 2012;82:691-7.
17. Loftus BP, Artun J, Nicholls JI, Alonzo TA, Stoner JA. Evaluation of friction during sliding tooth movement in various bracket-arch wire combinations. *Am J Orthod Dentofacial Orthop* 1999;116:336-45.
18. Thorstenson GA, Kusy RP. Resistance to sliding of orthodontic brackets with bumps in the slot floors and walls: Effects of second-order angulation. *Dent Mater* 2004;20:881-92.

19. Kusy RP, Whitley KQ. Frictional resistance of metal lined ceramic brackets versus conventional stainless steel brackets and development of 3D friction map. *Angle Orthod* 2001;71:364-74.
20. Shivapuja PK, Berger J. A comparative study of conventional ligation and self-ligation bracket systems. *Am J Orthod Dentofacial Orthop* 1994;106:472-80.
21. Choi S, Park KH, Cheong Y, Kim HK, Park YG, Park HK. Changes in ultrastructure and properties of bracket slots after orthodontic treatment with bicuspid extraction. *Scanning* 2011;33:25-32.
22. Amini F, Rakhshan V, Pousti M, Rahimi H, Shariati M, Aghamohamadi B. Variations in surface roughness of seven orthodontic archwires: An SEM-profilometry study. *Korean J Orthod* 2012;42:129-37.
23. Odegaard J, Segner D. Shear bond strength of metal brackets compared with a new ceramic bracket. *Am J Orthod Dentofacial Orthop* 1988;94:201-6.
24. Bishara SE, Oonsombat C, Soliman MM, Warren JJ, Laffoon JF, Ajlouni R. Comparison of bonding time and shear bond strength between a conventional and a new integrated bonding system. *Angle Orthod* 2005;75:237-42.
25. Ciocan DI, Stanciu D, Popescu MA, Miculescu F, Plotog I, Varzaru G, *et al.* Electron microscopy analysis of different orthodontic brackets and their adhesion to the tooth enamel. *Rom J Morphol Embryol* 2014;55 2 Suppl: 591-6.
26. Ghafari J. Problems associated with ceramic brackets suggest limiting use to selected teeth. *Angle Orthod* 1992;62:145-52.