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IN VITRO SHEAR BOND STRENGTH STUDY OF NEW AND RECONDITIONED STAINLESS STEEL ORTHODONTIC BRACKETS

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ABSTRACT:

This study was conducted to compare the shear bond strength between new and reconditioned brackets using four reconditioning techniques on two bracket base designs. Eighty specimens were divided into two equal groups according to bracket base designs, mesh-base brackets group (Ormco), and laser-base brackets group (Dentaurum). In each group, new brackets were bonded to premolar teeth and the bond strength was recorded as a base line (control 1). Each group was further subdivided into five equal subgroups as follows: first subgroup, debonded brackets were removed, new brackets were bonded and the bond strength was recorded as (control 2), for the remaining four subgroups, debonded brackets were rebonded after reconditioning by 30 µm silanated sandblasting, 50 µm non silanated sandblasting, acid bath, and carbide bur and their bond strengths measured. Statistical analysis revealed that there was significant difference in the bond strength between the two bracket base designs used (P = 0.000) as laser-structured base brackets demonstrated higher bond strength (mean= 18.7±5.2 MPa) compared to mesh-base brackets

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(mean= 14.6±4.2 MPa). Moreover, there was significant difference (P = 0.000) in bond strength between the different reconditioning techniques. On the contrary, there was no significant difference (P = 0.840) on the interaction between the type of bracket base design and reconditioning technique as both designs of bracket base responded similarly to each reconditioning technique. In conclusion, bracket reconditioning using sandblasting technique was efficient and technically simple, and might provide cost reduction for orthodontists and patients alike.

INTRODUCTION

In orthodontics, as well as in other dental fields, there is a trend to simplify the technical procedures to reduce operative time and treatment costs. Orthodontic bracket bonding must be strong enough to withstand stresses and shearing forces. Despite the material advancements of bonding and the increase in efficiency of treatment, a commonly encountered problem during the course of treatment that continues to be a challenge in clinical practice is a bracket bond failure which is usually the results of either the patient accidentally applying inappropriate forces to the bracket, poor bonding technique, or bracket base design.(1)

Bond failure of brackets not only can be frustrating for the practitioner, but also can significantly affect treatment efficiency and has an economic impact on a practice. (2) Bracket bond strength depends on several factors; bracket base retention mechanisms one of the factors that influences the shear bond strength of metal brackets. Mesh pad is the system most commonly used for retention.(3-6)

However, orthodontists are commonly faced with the decision of what to do with loose brackets, and or with inaccurately located brackets that need repositioning during treatment. One solution is to recondition the brackets. The reconditioning process basically consists of removing the bonding agent remnants from the bracket base, thus allowing the bracket to be reused without causing damage to the retention mesh while preserving its retentive characteristics.(7) A rapid office method of treating debonded brackets to produce clinically acceptable bond strengths with minimal changes in the physical properties of the brackets would benefit the profession economically.[8] The effect of reconditioning depends on the type of reconditioning process used, the type of steel from which the bracket is constructed, whether the bracket is milled or cast, and whether the bracket has a mesh pad or a non-mesh undercut integral pad.[9]

The purpose of this study was to compare the shear bond strength between new and reconditioned brackets using four reconditioning techniques on two bracket base designs.

The proposed null hypothesis was: no difference in SBS between mesh-based and laser-structured based brackets. There was a difference in SBS between new and reconditioned brackets but there was no difference in SBS between the reconditioning techniques using sandblasting, carbide bur, and acid bath.

MATERIALS AND METHODS

A total of eighty premolar teeth extracted for orthodontic purposes were collected for the purpose of this study. The teeth were washed, cleaned and stored in normal saline solution at room temperature to prevent dehydration until the time of mounting. Metal ring was used to make self cure acrylic blocks for holding the extracted premolars during testing procedures. Straight wire metal brackets with two different base designs for bonding on premolar teeth were tested. Table (I).

Eighty samples were divided equally into two main groups according to the bracket base designs: 40 samples: Mesh-base brackets group,40samples: Laser-structured base brackets group. In each group, new brackets were bonded and the bond strength was recorded as a base line (control 1). Each group was further subdivided into five subgroups as follows; the first subgroup: For calibration of the rebonding procedures, and the other four subgroups: For reconditioning techniques.

Calibration of the rebonding procedures (Sixteen samples)

Eight samples from each main group were used to investigate the effect of rebonding procedures on shear bond strength. Teeth from each main group were rebonded with new brackets. Rebond shear bond strength values were recorded as (control 2) to make sure that the rebonding surface treatment performed in the study produced reliable bond strength values compared to the control groups (control 1) and that the surface of enamel was not irreversibly damaged during the first debonding procedures.

Reconditioning subgroups (Sixty four samples)

Thirty two samples from each main group were further subdivided into four subgroups of eight teeth each according to the type of bracket reconditioning technique performed, Table (II). The same teeth were rebonded with their corresponding reconditioned brackets, and the rebond shear bond strength values were recorded.

Table (I): Types of bracket base designs tested.

Bracket Name	No.	Manufacturer	Base Design	Surface area(mm^2)
Mini 2000*	40	Ormco	Mesh-base	9.63
Discovery**	40	Dentaurum	Laser-structured base	12.93

Table (II): Reconditioning subgroups

New Brackets	Mesh-based brackets group (32)				Laser-structured based brackets group (32)			
Reconditioned Brackets	(8) 30 µm Silanated aluminum oxide sandblasting particle	(8) 50 µm Non-silanated aluminum oxide sandblasting particle	(8) Acid bath	(8) Carbide bur	(8) 30 µm Silanated aluminum oxide sandblasting particle	(8) 50 µm Non-silanated aluminum oxide sandblasting particle	(8) Acid bath	(8) Carbide bur

The buccal surface of each tooth was polished with a pumice paste using a rubber cup on a low-speed hand piece for 10 seconds. The enamel

*Ormco, California, USA
**Dentaurum, Ispringen, Germany.

surface was then thoroughly rinsed and dried with an air spray for 30 seconds. 37% phosphoric acid etchant was applied to the enamel surface for 30 seconds using disposable microbrushes, followed by rinsing for 20 seconds using air-water spray, and drying with air spray for 20 seconds. The enamel bond was then applied in a thin coat to etched enamel using disposable microbrushes. Composite was applied to each bracket base, then, all brackets were bonded approximately in the center of the buccal surface of the teeth with 250 g force for 5 seconds to ensure uniform adhesive thickness.[10] The excess composite was removed with a dental probe. The adhesive bracket tooth interface was exposed to the curing light for 20 seconds at a distance of 5 mm around the four edges of the brackets. The bonded teeth were stored in normal saline for 24 hours before testing. All brackets were bonded with the same light-cured bonding system* and the same technique.

Each specimen was fixed on a holding ring positioned in the lower table of the universal testing machine**. A chisel was secured to the upper table applied perpendicularly between the bracket base and tooth. The testing machine was turned on at a crosshead speed of 0.5 mm per minute, to shear the bracket off the tooth surface. The force required to debond each bracket was recorded in Kilograms on a monitor attached to the machine, and converted to megapascals as ratio of kilograms to the bracket surface area (mm^2).

After bond fracture (failure), brackets and enamel surfaces in each group were examined under magnification with stereomicroscope for the amount of adhesive remaining on the bracket base and the site of bond fracture (failure) using ARI score according to the index developed by Artun and Bergland.[11]

Score (0) = All adhesive is left on the bracket base.

Score (1) = More than 50% of the adhesive is left on the bracket base.

Score (2) = Less than 50% of the adhesive is left on the bracket base.

Score (3) = No adhesive is left on the bracket base.

* Ormco, California, USA.
** Comten industries, inc., Florida, USA.

Reconditioning procedures

The residual composite resin on each tooth was carefully removed from the enamel with 12-fluted tungsten carbide bur in a low-speed hand piece at a speed of 25,000 revolutions per minute (rpm) under dry conditions. The removal of resin was considered complete when no resin was apparent on visual inspection. To prevent dehydration, all specimens were stored in a tightly sealed box lined by cotton soaked with normal saline until they were randomly assigned to the rebonding subgroups. Debonded brackets in each subgroup were reconditioned as the following:

Sandblasting Subgroups

The previously bonded brackets were reconditioned by sandblasting technique.Each bracket was held approximately 5mm from the tip of a portable sandblasting unit (Micro Etcher II)* and etched with 30 µm silanated aluminum oxide particles or with 50 µm non-silanated aluminum oxide particles until all visible bonding material was removed from the bracket base. Each bracket base was sandblasted for 20-40seconds (depending on the mount of residual bonding agent) under 5.5 bars (80 psi) line pressure. The bracket was then rinsed and dried with compressed air.

Acid bath Subgroups

The previously bonded brackets were reconditioned by acid bath technique. The flame tip of a gas torch flame was pointed at the bracket base for a few seconds until the bonding agent started to ignite and burn. The bracket was then submerged for 3 minutes in a solution of 32% hydrochloric acid. Then, the bracket rinsed under running water for 30 to 60 seconds, air dried and ready for rebonding.

Carbide bur Subgroups

The previously bonded brackets were reconditioned using 12-fluted tungsten carbide burs operated on low-speed hand piece at a speed of 25,000 rpm for approximately 25 seconds until all residues had been removed.

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*Danville, California, U.S.A.

Surface roughness of reconditioned brackets

Specimens were ultrasonically cleaned and fixed on the measuring table. Bracket base surface was placed parallel to horizon. The surface roughness was measured using contact stylus which travelled 4 mm on the surface. Average surface roughness R_a (average peak valley value) was measured 5 times on each specimen.

Scanning Electron Microscope (SEM) examination

After reconditioning of debonded brackets for each subgroup, they examined under magnification with scanning electron microscope, at operating magnification ranging from 200 to 1000x at 25 KV, to explore the effect of reconditioning techniques on bracket bases.

Rebond shear bond strength testing (Rebonding procedures)

The same teeth, after reconditioning, in each subgroup were rebonded with their corresponding reconditioned brackets, and the rebond shear bond strength values were evaluated and recorded using the same procedures in the initial bonding and initial shear bond strength testing.

STATISTICAL ANALYSIS

Data on the value of the shear bond strength of each group and subgroup was collected and tabulated. Descriptive statistics including the mean, standard deviation, minimum, and maximum were calculated, and the data was statistically analyzed by one-way and two-way analysis of variance (ANOVA) and Bonferroni post hoc tests ($\alpha = 0.05$).

RESULTS

Statistical analysis revealed that there was significant difference in the shear bond strength between the two bracket base designs used (F value = 29.357 and P value = 0.000) as laser-structured base brackets demonstrated higher bond strength (mean = 18.7 ± 5.2 MPa) compared to mesh-base brackets (mean = 14.6 ± 4.2 MPa). Moreover, there was significant difference (F value = 17.967 and P value = 0.000) in bond strength between the different reconditioning techniques. On the contrary, there was no significant difference (F value = 0.411 and P value = 0.840) on the interaction between the type of bracket base design and reconditioning technique as both designs of bracket base responded similarly to each reconditioning technique (Table III). Descriptive statistics are summarized in (Table IV) and (Figs. 1 & 2).

The results of the adhesive remnants were graded as per ARI[11] and showed significant differences between the two different bracket base designs. Bond failure waslocated at the bracket-adhesive interface (ARI score of 3) with the mesh base brackets in 75% of the specimens indicating a greater trend for most of theadhesive to remain on the tooth with a distinct impression of the bracket mesh after debonding. Bond failure was located at the enamel-adhesive interface (ARI score of 0) with the laser-structured base brackets in 85% of the specimens. This indicated a greater trend for all adhesive toremain on the base after debonding (Fig. 3).

The results of the surface roughness measurements indicated that no correlation existed between bond strength and surface roughness (Table V). Examination of the bracket bases with scanning electron microscope revealed that the new brackets had smooth bases with clean retentive areas. Mesh-base showed multi-stranded wire structure, and the laser-structured base had small grains and rounded beads (Fig.4). Debonded both types of brackets, the retentive areas were filled with adhesive remnants (Fig.5). In 30 µm silanated sandblasting subgroups the two types of bracket bases demonstrated dull and rough bases with clean retentive areas. The retentive areas were well-defined. Adhesive remnants were completely removed except in certain areas under the mesh-base (Fig.6). In 50 µm non-silanated sandblasting subgroups, both bracket bases demonstrated also dull but morerough bases. The retentive areas were clean but less well-defined (Fig.7). In acid bath subgroups, incomplete removal of adhesives from both bracket bases was shown. The retentive areas were filled with adhesive, even though no adhesive was remaining on the bracket. Only the overhanging adhesive was found to have been removed (Fig.8). In carbide bur subgroups, also showed incomplete removal of adhesive from the bracket bases. The retentive areas and the adhesive were found scraped to the same level and the adhesive was removed to that level only. Flattening and loss of retentive areas was seen (Fig.9).

Table (III): The statistical comparisons of the different groups and subgroups.

Source	F	*P*
Groups	29.357	0.000
Subgroups	17.967	0.000
Groups * Subgroups	0.411	0.840

Table (IV): The descriptive statistics of the different groups and subgroups.

Bracket base	Groups and Subgroups	Mean	Std. Dev.
Mesh-Base Brackets	Control 1: initial SBS	14.6218	4.23530
	Control 2: rebond new brackets	15.3325	2.91228
	30 µm silanated sandblasting	14.1050	2.33531
	50 µm non-silanated sandblasting	11.6650	2.99456
	Acid Bath	8.3200	3.10881
	Carbide Bur	7.2550	4.00662
Laser-Base Brackets	Control 1: initial SBS	18.7460	5.21543
	Control 2: rebond new brackets	18.8963	3.14399
	30 µm silanated sandblasting	20.6750	3.56039
	50 µm non-silanated sandblasting	15.1088	2.22130
	Acid Bath	12.1700	1.95479
	Carbide Bur	10.2463	1.51222

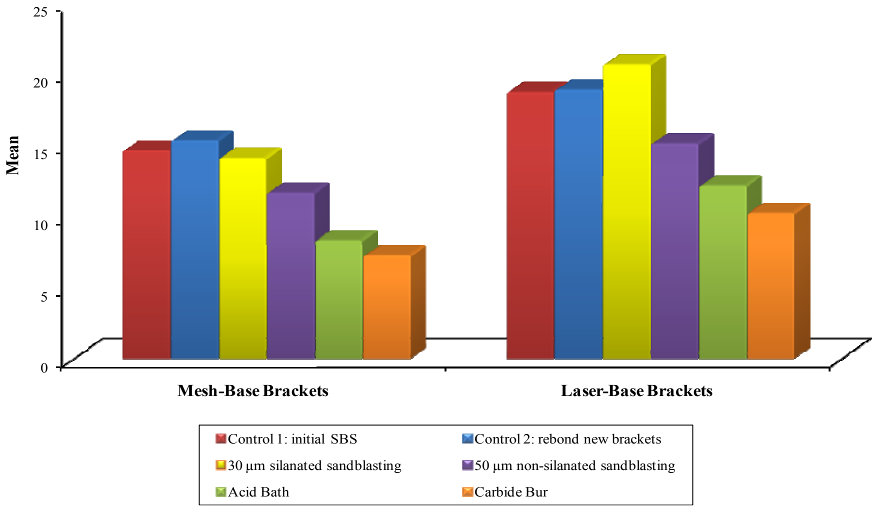


Fig. 1: Histogram showing mean shear bond strengths of the all groups and subgroups.

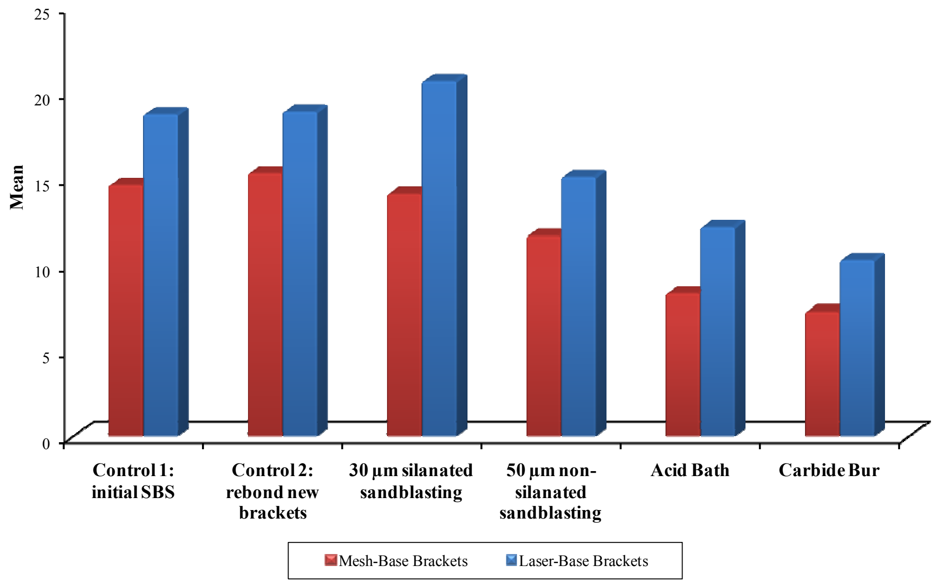


Fig. 2: Histogramshowing comparisons of meanshear bond strengths between the different groups and subgroups.

Table (V): Mean surface roughness between the different groups and subgroups.

Samples		**Maximum Height, R_t, (mm), Mean Value**
Mesh-Base Brackets	Debonded	0.3071
	30 µm silanated sandblasting	0.3160
	50 µm non-silanated sandblasting	0.4238
	Acid bath	0.3734
	carbide bur	0.3076
Laser-Structured Base Brackets	Debonded	0.1516
	30 µm silanated sandblasting	0.1931
	50 µm non-silanated sandblasting	0.2988
	Acid bath	0.2444
	carbide bur	0.0703

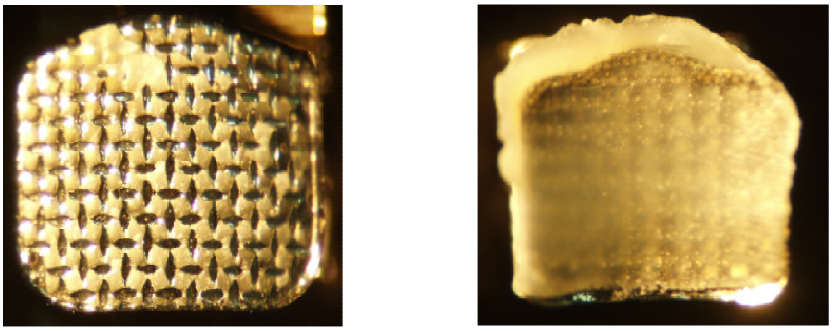


Fig. 3: Debonded brackets with adhesive on bracket base under Stereomicroscope; mesh-base bracket (left), laser-base bracket (right).

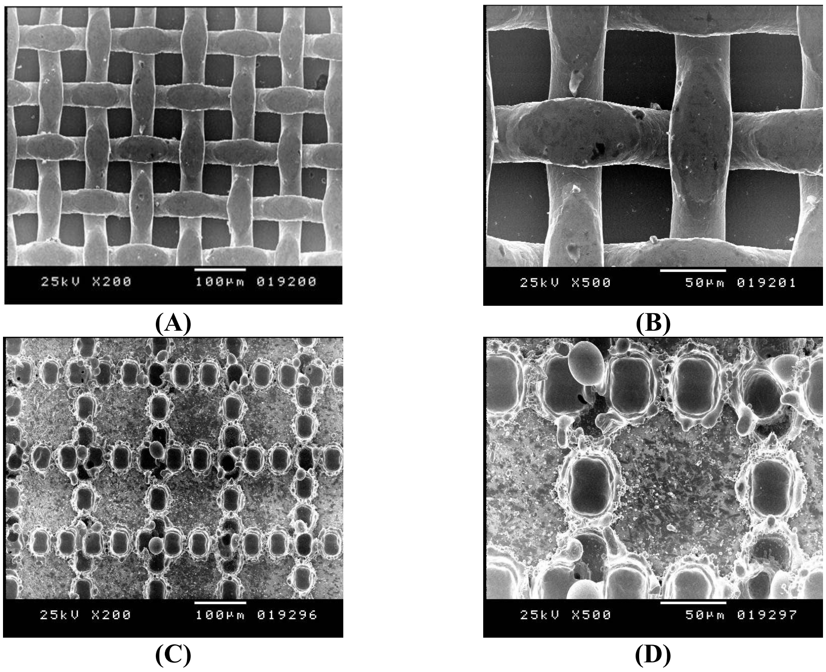
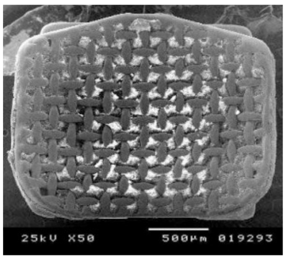
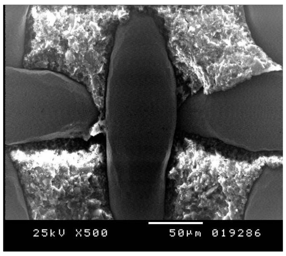


Fig. 4: Scanning electron micrographs of new brackets tested under different magnifications; **(A,B)** mesh-base brackets **A:** magnification_200, **B:** magnification_500. **(C,D)** laser-structured base brackets **C:** magnification_200, **D:** magnification_500.



(A)



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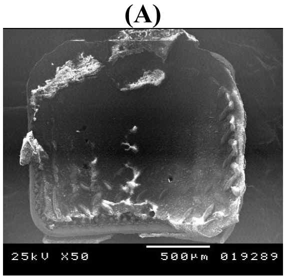
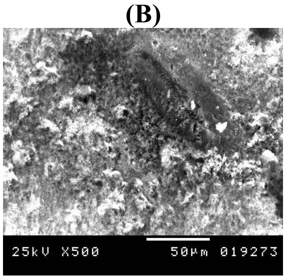
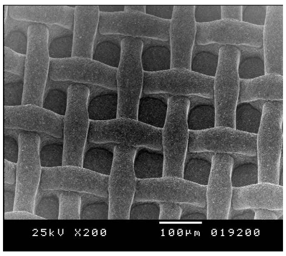


(C)

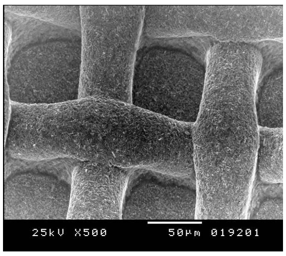


(D)

Fig. 5: Scanning electron micrographs of 2 types of brackets after debonding: **(A,B)** mesh-base brackets **A:** magnification_50, **B:** magnification_500. **(C,D)** laser-structured base bracket **C:** magnification_50, **D:** magnification_500.



(A)



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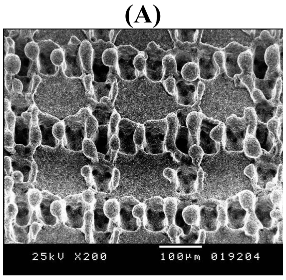

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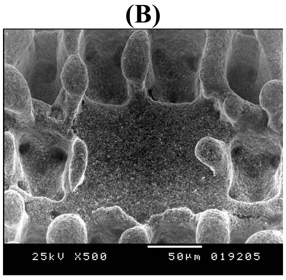
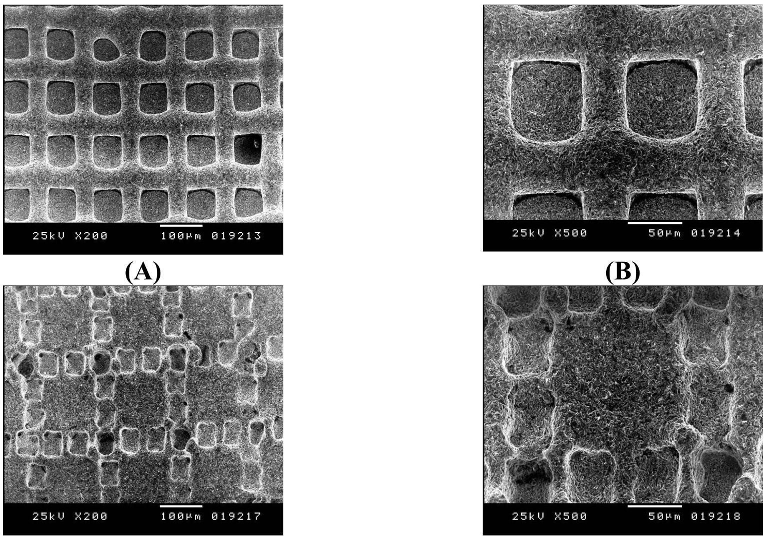


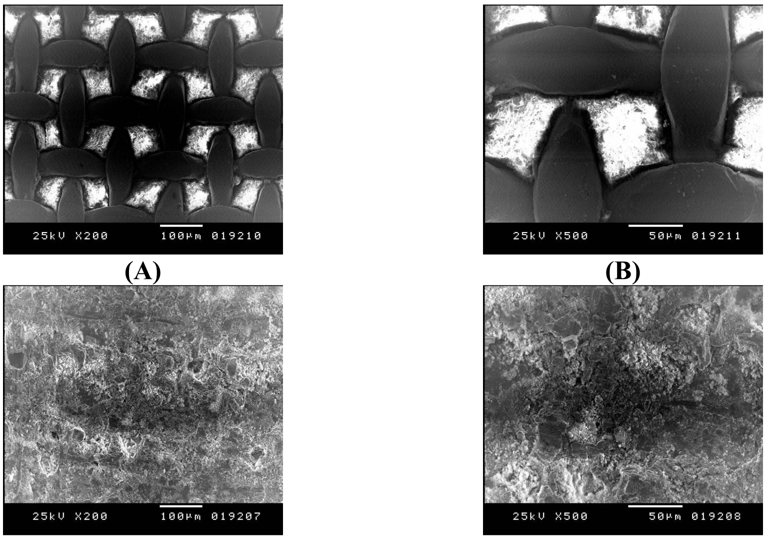
(D)

Fig. 6: Scanning electron micrographs after reconditioning with 30 µm silanated aluminum oxide sandblasting particles. **(A,B)** mesh-base brackets **A:** magnification 200, **B:** magnification_500.**(C,D)** laser-structured base brackets **C:** magnification _ 200, **D:** magnification_500



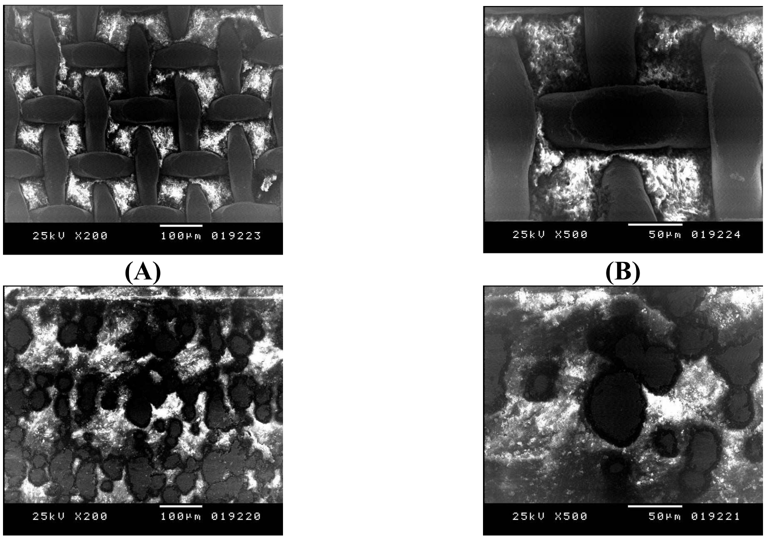
(C) (D)

Fig. 7: Scanning electron micrographs after reconditioning with 50 µm non-silanated aluminum oxide sandblasting particles.**(A,B)** mesh-base brackets **A:** magnification _ 200, B: magnification_500. **(C,D)** laser-structured base brackets **C:** magnification _ 200, **D:** magnification_500.



(C) (D)

Fig. 8: Scanning electron micrographs after reconditioning with acid bath. **(A,B)** mesh-base brackets **A:** magnification 200, **B:** magnification_500. **(C,D)** laser-structured base brackets **C:** magnification 200, **D:** magnification_500.



(C) **(D)**

Fig. 9: Scanning electron micrographs after reconditioning with carbide bur. **(A,B)** mesh-base brackets **A:** magnification _ 200, **B:** magnification_500. **(C,D)** laser-structured base brackets **C:** magnification _ 200, **D:** magnification_500.

DISCUSSION

Based on the presented data, the null hypothesis was rejected. There was a difference in SBS between mesh-based and laser-structured based brackets. There was no difference in SBS between new and reconditioned brackets but there is a difference in SBS between the reconditioning techniques using sandblasting, carbide bur, and acid bath. The results of this study clearly indicated that bond strength was influenced by the retention mechanism of the laser-structured base bracket base. The laser-structured base bracket retention mechanism provided greater bond strength (mean = 18.7 ± 5.2 MPa) when compared with the mesh-base bracket retention mechanism (mean = 14.6 ± 4.2 MPa).

Reynolds(12) in his study has suggested 5.9 to 7.8 MPa as the optimal bond strength required for bonding brackets to enamel. The results of this bond strength test show that laser-structured base bracket has more than optimal bond strength required for successful bonding. This increase in the bond strength for laser-structured base bracket may be due to the complicated microscopic and macroscopic void network developed due to laser etching provided better resin penetration and mechanical locking of orthodontic adhesive than the mesh base bracket, as shown on scanning electron microscope (SEM) (Fig. 4). Previous studies[13,14] found that laser-structured base brackets revealed greater bond strength values when compared to mesh-base brackets which is in agreement with the current findings.

By comparing ARI scores of these two types of bracket designs, it was evident that the laser-structured base bracket had bond failure in the enamel-adhesive interface and the mesh-base bracket had bond failure in the bracket-adhesive interface. The reason for increased adhesive remaining on the laser-structured base was due to the presence of micro and macro grooves on the base, which aided in better penetration of adhesive through capillary action. This shift in the site of bond failure suggests that, there could be less iatrogenic damage caused to enamel surface after clean up procedures following debonding indicating that less chair-time would be required for removal of the adhesive[13].

Several studies[15-17] that assessed the effectiveness and safety of rotary instruments, advocated the use of Tungsten Carbide Burs (TCB) for the removal of the adhesive resin from the enamel surface either with adequate air cooling or suggested water spray instead of air cooling. In this work, air cooling was preferred to water cooling to assist in the observation of the resin remnants. In this study, reconditioning the enamel using a (TCB) following by acid-etching was found to produce mean shear rebond strength higher but statistically non significant from the initial shear bond strength. This was also consistent with Eminkahyagil et al. (2006)[18] who studied the effect of resin removal methods on enamel surface and shear bond strength of rebounded brackets. The authors suggested that the removal of residual resin with the tungsten carbide bur then repeating the acid-etching produces some kind of roughened surface that was not present at the time of initial bonding.

In the literature, there is no consensus on how the rebond strength compares with initial bond strength. Some authors(5,19,20) have reported that initial bond strength is significantly greater than rebond strength. On the contrary, other studies(21-23) reported increase in shear bond strength with chemical-cured bonding systems after rebonding. These controversies could be attributed to the types of bracket and adhesive used, reconditioning methods differences, and several laboratorial proceedings adopted. Several studies(1,8,24-25) found that there was no significant differences between the initial and rebond shear bond strength which is consistent with this study.

In this study, no significant difference was observed in rebond bond strength when using new or reconditioned brackets. In sandblasting subgroups, the changes in the macroscopic structure caused by the debonding process and the changes in the microscopic structure caused by sandblasting of the bracket base did not detrimentally affect the rebond bond strength. This results are consistent with the results of similar studies(26-28)who compared the in vitro shear bond strengths of previously failed metal brackets subjected to sandblasting with new untreated brackets and found no significant differences in shear bond strength between the two groups. The findings of no statistically significant differences in mean bond strength between the new brackets and brackets reconditioned by sandblasting tested in this study, supports the use of sandblasting as a viable procedure when rebonding accidentally lost brackets.

In the present study, the use of 30 µm silanated particles or 50 µm non-silanated particles for bracket reconditioning had similar efficacy, due to the absence of statistically significant difference between these reconditioning subgroups. Consequently, the micro-roughness created by different sized particles promoted bond strength that was not significantly different when compared to the control groups. However, 50 µm non-silanated particles produced some damage to the retentive areas as shown on (SEM) (Fig.7).

Dawjee et al. (2004)(29) described a simple, quick, and inexpensive way to clean a bracket after burning the adhesive (acid bath), and reported that a bracket that has been reconditioned with acid bath looks more like a new bracket than one that has been reconditioned using a flame and microetcher, and therefore would be more esthetically pleasing for the patient. In this study, the acid bath subgroups produced significantly deceased shear bond strength when compared to the control groups. This could be explained with scanning electron microscope that showed incomplete removal of adhesive from the bracket bases and the retentive areas were filled with adhesive, even though no adhesive was remaining on the bracket. Only the overhanging adhesive was found to have been removed. Moreover, carbide bur subgroups produced significantly deceased shear bond strength when compared to the control groups. These findings are similar to Kulandiavelu et al. (2009)(30) who also found that using tungsten carbide bur produced significantly decreased bond strength than the control group, the grinding of the bracket base using tungsten carbide bur appear quick, simple and easy to perform, but the grinding leaves behind a smooth surface with much of the retentive areas being scrapped off as shown on SEM (Fig.9). This in turn leads to low bond strength values.

However, the comparisons of mean shear bond strengths of reconditioning subgroups in this study showed that, no significant difference between acid bath and carbide bur subgroups because both were not effective for complete removal of adhesive from the bracket bases. Both subgroups were not significantly different when compared to 50 µm non-silanated particles sandblast subgroup but were significantly decreased when compared to 30 µm silanated particles sandblast subgroup. This indicated that 30 µm silanated particles sandblast subgroup had the highest mean shear bond strength than the other reconditioning subgroups (Fig. 6).

The results of the surface roughness measurements in this study indicated that no correlation existed between bond strength and surface roughness. Previousstudies(31,32) in the literature found that no correlation between the surface roughness and bond strength which is consistent with this study. High surface roughness measurements and low bond strength values were obtained with mesh-base brackets group compared to the laser-structured base brackets group. When considering reconditioning subgroups, the surface with the highest roughness values did not show high bond strength, and there was no correlation between the roughness created by reconditioning techniques and shear bond strength. The highest observed surface roughness measurements was caused by 50 µm non-silanated sandblasting and acid bath subgroups compared with other subgroups which is in contrast to what was expected.

CONCLUSIONS

1. Bracket reconditioning could be considered as a viable option to the clinician as there are no statistically significant differences between the mean shear bond strength and the total bond failure rate of new and reconditioned brackets.
2. Office reconditioning of stainless steel brackets by sandblasting technique showed the highest bond strength among the reconditioning techniques tested. This study confirms sandblasting as the simplest, most efficient manner of immediately reconditioning deboned brackets.

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