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ORIGINAL RESEARCH

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Comparison of Bond Strength of Brackets with Foil Mesh and Laser Structure Base using Light Cure Composite Resin: An *in vitro* Study

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ABSTRACT

Background and objectives: The purpose of this in vitro study was to evaluate the bond strength of the laser-etched base bracket, site of bond failure, and evaluate for enamel remnants on the bracket base after debonding, when compared to foil mesh base bracket.

Materials and methods: Sixty noncarious, human premolar extracted for the orthodontic treatment were used for this study. The teeth were randomly divided into two groups containing 30 teeth each, which were bonded with laser-etched base bracket and mesh base bracket using light cure resin. The tensile and mechanical bond strength was tested after 24 hours using TIRA. The forces recorded during debonding were measured in Newton and final readings were tabulated in megapascals (MPa).

After debonding, the amount of residual adhesive and enamel detachment on the bracket base were assessed according to adhesive remnant index (ARI) and enamel detachment index (EDI) using stereomicroscope and energy dispersive X-ray spectrometer.

Results: The laser-etched base bracket showed statistically significant higher results than mesh base bracket. Mann-Whitney test indicated that laser-etched base bracket had significantly higher tensile bond strength of 8.47 MPa (SD ± 0.84), fatigue strength of 7.75 MPa (SD ± 0.79) compared to mesh base bracket with tensile bond strength of 5.53 Mpa (SD ± 0.89) and fatigue strength of 5.17 MPa (SD ± 1.15).

Adhesive remnant index score indicated that laser-etched base bracket had ARI score of 3 for most of the bracket, when compared to mesh base bracket. This was statistically significant.

Enamel detachment index scores indicated that less than 10% of enamel detachment occurred in both the types of brackets, which was not statistically significant.

Conclusion: Laser-etched base bracket showed superior bond strength, when compared to the foil mesh base bracket. The site of bond failure of these laser-etched base bracket was at the interface of enamel-adhesive and did not induce any significant enamel detachment. Thus, we can conclude that laser-etched base bracket is a promising step toward achieving an ideal bracket base design for successful bonding.

Keywords: Adhesive remnant index, Enamel detachment index, laser-etched base bracket, Mesh base bracket.

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INTRODUCTION

Orthodontic brackets play a major role in the orthodontic appliance system. It transmits forces from the wire to the periodontal ligament tissues to produce tooth movement.

The demand for more esthetic orthodontics, led to the development of newer brackets with a more pleasing and acceptable appearance.[1] One such development was the stainless steel brackets with a variety of bonding pads and retention mechanisms.[2] The different types of bonding pads available are perforated base, mesh foil base, and sintered base.[3-5] Of these, Mesh based is the most commonly used bracket because they retain less plaque and have mesh size ranging from 60 to 100 gauge, which provide optimal bond strength. These mesh wires are spot-welded, laser-welded, Brazed and Laminated.[6-8]

As the demand for esthetic bracket increased, the brackets became smaller and smaller resulting in a reduced retentive surface area, which ultimately reduced the bond strength of the bracket.[9] Due to these developments, variables, such as weld spots, mesh wire size, etc. became more important to the overall bond strength of the bracket bases.[10-13]

Although adequate results with mesh bases may be obtained in clinical practice, failures did occured at the interface between the adhesive resin and the mesh, which indicated that more clean up time was required at the end of the treatment and subsequent enamel loss.[3,5] Another problem with this type of bracket was the technical difficulty and the time required in manufacturing these bracket.

Due to these problems of mesh base bracket, metal injection molding brackets were introduced. Some made the base resemble the standard foil mesh pad design, micro-etched pattern, serrations, and undercuts to improve the bond strength.[14-16] Thus, in an attempt to save chair side time during de bonding and reducing the frequency of bond failure prompted manufacturers to improve bracket base morphology. Therefore, with a quest for good bracket base that could provide stronger bond strength, numerous studies were conducted. It was found that the overall bond strength may be attained by treating the bracket base with materials, which resembles the microscopic surface characteristics of freshly etched tooth enamel.[17-20] With this in mind laser etching of the bracket base was introduced. These laser-etched base brackets are made by metal injection molded of stainless steel. The smooth surface of these bracket bases are then treated by powerful Nd:YAG laser to create sufficient retention for adhesion.[21-23]

Hence, this study was under taken to evaluate the bond strength of laser-etched base brackets, site of bond failure and compare it with most commonly used mesh base brackets and also to verify the manufacturers claim that the computer-aided laser cutting of base to be superior over the mesh base bracket.

MATERIALS AND METHODS

- Thirty metal brackets with laser structured base (Equilibrium-Dentaurum)
- Thirty metal brackets with foil mesh base (Gemini —3M Unitek)
- Polyvinyl chloride (PVC) sleeves
- Auto polymerizing acrylic resin
- Light cure composite (3M Unitek)
- Light cure unit (Spectrum 800, Dentsply)
- 0.012” ligature wire (Leone)
- Scanning electron microscope (SEM) with Energy dispersive X-ray spectrometer (LEO 440 I)
- 0.019 × 0.025" stainless steel wire (Inno Brace Orthodontics)
- Traveling microscope
- Universal testing machine (TIRA 2820S, Germany)
- Stereomicroscope (Lawrence and Mayo).

SELECTION AND GROUPING OF TEETH

In this study, 60 healthy, noncarious human maxillary first premolar teeth, which were extracted for orthodontic treatment were collected. These teeth were thoroughly cleaned for any soft tissue debris, hard tissue debris, and blood and were stored immediately in normal saline at room temperature prior to the use. The teeth were randomly divided into the following groups for easy identification:

Group I: Thirty maxillary first premolars randomly selected underwent tensile strength test.

Out of 30 teeth, 15 teeth were bonded with laser structured base bracket. Remaining 15 teeth were bonded with foil mesh base bracket.

Group II: Thirty maxillary first premolars randomly selected underwent mechanical fatigue test.

Out of 30, 15 teeth were bonded with laser structured base bracket. Remaining 15 teeth were bonded with foil mesh base.

Bracket Adhesion

Enamel surface of the extracted teeth was cleaned and polished for 15 seconds using slurry of pumice and rubber cup. Etching was performed using a 37% phosphoric acid gel for 15 seconds. The teeth were rinsed and dried with oil free compressed air. Brackets selected for the study were then bonded to the center of the labial surface of the clinical crown using light cure composite according to the instructions of the manufacturer. The teeth were later examined under a magnifying lens following bonding and any excess adhesive was removed using a sickle scaler. Then curing of adhesive was done with a visible light cure gun for 40 seconds. The specimens were then stored in saline till the bond strength test was done.

Method of Mounting

The maxillary premolar teeth with the bonded 0.022 slot Roth bracket were embedded in Polyethyl Methacrylate confined in a PVC sleeve of approximately 30 mm in length and 25.6 mm diameter. These specimens were then oriented vertically, so that the root portion was embedded in the acrylic and exposing only the crown portions of the teeth. Dental surveyor and a plumb line tied to the wire slot of the bracket were used to orient the teeth vertically in the center of the PVC sleeve. The parallelism of the bonded teeth was then checked with the dental surveyor keeping the surveyor arm parallel to the plumb line. The bonded teeth with the plumb line were then mounted in the PVC sleeve with the help of a tooth-holding stand, which could be raised or lowered.

A specially designed mounting jig with a graph sheet attached was used to align the teeth in the center of the PVC sleeve. The surveying arm with aligning rod and the plumb line was adjusted till the aligning rod and the plumb line were parallel to each other. The plumb line was then cut with the help of a sharp scissor taking care not to disturb the alignment.

The bonded tooth was then lowered into the PVC ring such that the root portion of the tooth specimen was within the PVC sleeve and subsequently cold cure acrylic was poured and allowed to harden. These bonded teeth with bracket were then numbered for identification. Later these specimens were stored in normal saline at room temperature until testing was done.

Mechanical Testing

The bond strength of these specimens was tested with the help of universal testing machine (TIRA). A crosshead speed of 6 and 16 mm per minute was used to test the tensile strength and mechanical fatigue strength respectively.

The PVC sleeve, holding the teeth was positioned so that the long axis of the tooth and the bracket base was perpendicular to the direction of the applied load. A 0.019 × 0.025" stainless steel wire placed into the bracket slot and firmly tied with a 0.12 mm steel ligature wire and connected to the debonding machine, such that the applied force was perpendicular to the long axis of the tooth.

This specimen was then tested for tensile strength with a crosshead speed of 6 mm per minute and mechanical fatigue at a crosshead speed of 16 mm per minute. The load was applied till the bond failure occurred and the force required to debond the bracket were measured in Newton's and converted into megapascal (MPa).

Once the debonding occurred, the brackets were then placed in the respective numbered glass bottles for identification.

These debonded brackets were then examined under the stereomicroscope and the adhesive remnant index (ARI) was used to assess the adhesive remaining on the bracket base at 10× magnification.

Subsequently, the specimen was tested for detached enamel remaining on the bracket base using the energy dispersing X-ray spectrometer and enamel detachment index (EDI) was assessed.

Determination of Remaining Residual Adhesive after Debonding

The bracket bases were examined under stereomicroscope to assess the site of bond failure and assess the amount of adhesive left on the bracket base after debonding (Figs 1 and 2). Any adhesive remnants were graded as per ARI developed by Artun and Bergland.[22]

- 0—No adhesive left on the tooth
- 1—Less than half of adhesive left on the tooth
- 2—More than half of adhesive left on the tooth
- 3—Entire adhesive left on the tooth.

Determination of Enamel Detachment after Debonding

All the bracket bases were examined under energy dispersive X-ray spectrometer to assess the quantity of

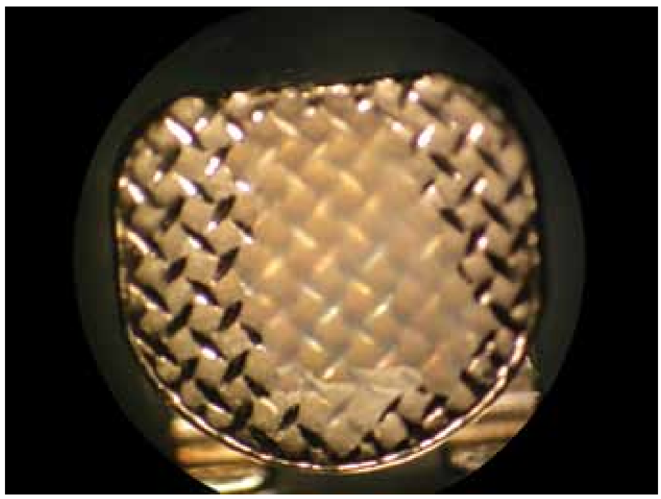

Fig. 1: Mesh base bracket with adhesive on bracket base under stereomicroscope

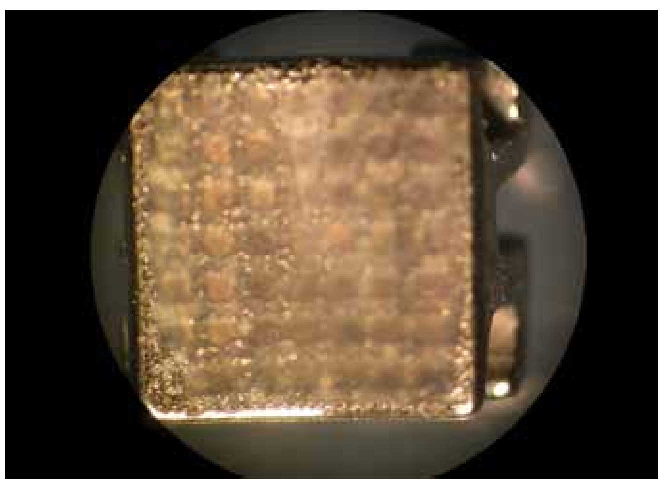

Fig. 2: Laser-etched base bracket with adhesive on bracket base under stereomicroscope

detached enamel remaining on the bracket base after de bonding.

Any enamel detachment was graded as per.

- 0—No enamel detachment
- 1—Less than 10% of enamel detachment
- 2—More than 10% but less than 30% of enamel detachment.

METHOD OF STATISTICAL ANALYSIS

The data were collected on forms and entered into a Microsoft Excel Worksheet and analyzed using statistical package for the social sciences (SPSS) (version 7.5). The following methods of statistical analysis have been used in this study. The results were averaged (mean + standard deviation) for each parameter is presented in Tables.

- Mann-Whitney U test was applied to find out the significant difference between mean values of tensile bond strength between two independent methods.
- The proportion was compared using Chi-square test of significance.

Chi-square test for r × c tables

	Group I	*Group II*	*Total*
Category 1	O_{11}	O_{12}	n1.
Category 2	O_{21}	O_{22}	n2.
Category 3	O_{31}	O_{32}	n3.
Total	n.1	n.2	n.

In all above test p-value less than 0.05 was taken to be statistically significant.

RESULTS

The present study aims at assessing and comparing the tensile bond strength and mechanical fatigue of laser-etched base and mesh based bracket, evaluate the site of bond failure and evaluate for enamel remnants on the bracket base.

- The 30 samples tested for tensile bond strength at cross head speed of 6 mm/min was recorded in Newton's and converted to MPa as shown in Table 1.
- The 30 samples tested for mechanical fatigue strength at cross head speed of 16 mm/min was recorded in Newton and converted to MPa as shown in Table 2.

In each group mean and standard deviation of tensile and mechanical fatigue strength were calculated as illustrated in Table 3.

The difference in bond strength between the laser-etched bracket and mesh based bracket in two groups were assessed by Mann-Whitney test.

The mean values between laser-etched base bracket and mesh based bracket was statistically significant ($p < 0.05$) (Table 4). The mean values of group I showed that laser-etched bracket had superior tensile bond strength value of mean 8.47 MPa than the mesh-based bracket with a mean value of 5.53 MPa (Table 4).

Table 1: Tensile strength of the brackets at 6 mm speed in MPa

Sl. no.	*Laser base bracket*	*Sl. no*	*Mesh base bracket*
1	8.74	16	7.7
2	8.20	17	7.1
3	9.8	18	4.5
4	9.1	19	5.2
5	7.1	20	5.1
6	9.3	21	5.3
7	10.2	22	6.0
8	8.1	23	5.5
9	8.3	24	6.9
10	8.5	25	5.1
11	7.7	26	5.3
12	8.1	27	5.1
13	7.4	28	4.2
14	8.4	29	5.1
15	8.6	30	5.2

Table 2: Tensile strength of the brackets at 16 mm speed in MPa

Sl. no.	*Laser base bracket*	*Sl. no.*	*Mesh base bracket*
31	8.7	46	4.9
32	8.4	47	5.9
33	7.5	48	5.3
34	8.1	49	5.1
35	7.3	50	7.0
36	6.8	51	5.1
37	6.2	52	5.6
38	8.4	53	5.4
39	8.6	54	4.2
40	8.3	55	6.2
41	6.8	56	5.3
42	8.2	57	6.4
43	6.8	58	5.2
44	8.1	59	3.6
45	8.0	60	2.3

The mean values of group II also showed that laser-etched bracket had superior tensile fatigue strength value of mean 7.75 MPa than the mesh based bracket with a mean value of 5.17 MPa (Table 4).

ADHESIVE REMNANT INDEX SCORES

After debonding, the bracket base was observed under stereomicroscope at 10× magnification to determine the amount of adhesive remaining on the base (Figs 1 and 2). Adhesive remnants were graded as per ARI developed by Artun and Bergland (Table 5).

Chi-square test was used to compare the pattern of ARI scores between two groups. This test showed that, there was statistically significant difference between the two groups with respect to ARI scores. It was observed that more adhesive remained on the bracket base of laser-etched bracket (ARI-3), when compared to mesh based as illustrated in Table 6.

Table 3: Mean and standard deviation value of bond strength in different methods

Method	*Tensile bond strength*	*N*	*Mean*	*Median*	*SD*	*Min.*	*Max.*
Laser base	6 mm	15	8.47	8.3	0.84	7.1	10.2
	16 mm	15	7.75	8.1	0.79	6.2	8.74
Mesh base	6 mm	15	5.53	5.2	0.89	4.2	7.2
	16 mm	15	5.17	5.3	1.15	2.3	7

Table 4: Comparison of mean values of bond strength in different methods

Tensile bond strength	*Method*	*N*	*Mean*	*SD*	*Mean rank*	*Mann-Whitney 'U' value*	*p-value*	*Inference*
6 mm	Laser base	15	8.47	0.84	22.9	1.500	0.001	S
	Mesh base	15	5.53	0.89	8.10	—	—	
16 mm	Laser base	15	7.75	0.79	22.6	5.500	0.001	S
	Mesh base	15	5.17	1.15	8.37	—	—	

S: Significant

Table 5: Adhesive remnant index

Sl. no.	*Laser base bracket*	*Sl. no.*	*Mesh base bracket*	*Sl. no.*	*Mesh base bracket*	*Sl. no.*	*Laser base bracket*
1	3	16	1	31	3	46	2
2	2	17	2	32	3	47	0
3	3	18	1	33	2	48	3
4	2	19	3	34	2	49	1
5	3	20	1	35	3	50	1
6	2	21	3	36	3	51	1
7	3	22	2	37	3	52	0
8	3	23	1	38	3	53	1
9	3	24	1	39	3	54	0
10	2	25	3	40	3	55	1
11	3	26	2	41	3	56	2
12	3	27	1	42	3	57	1
13	1	28	1	43	1	58	0
14	3	29	3	44	2	59	0
15	2	30	2	45	3	60	3

Table 6: Comparison of adhesive remnant index score among different methods

	ARI Score				
Method	*0*	*1*	*2*	*3*	*Total*
Laser base	1 (3.3)	6 (20.0)	12 (40.0)	11 (36.7)	30 (100.0)
Mesh base	5 (16.8)	13 (43.3)	6 (20.0)	6 (20.0)	30 (100.0)
Total	6	19	18	17	60

χ^2 = 8.72; DF = 3; p = 0.033 (significant)

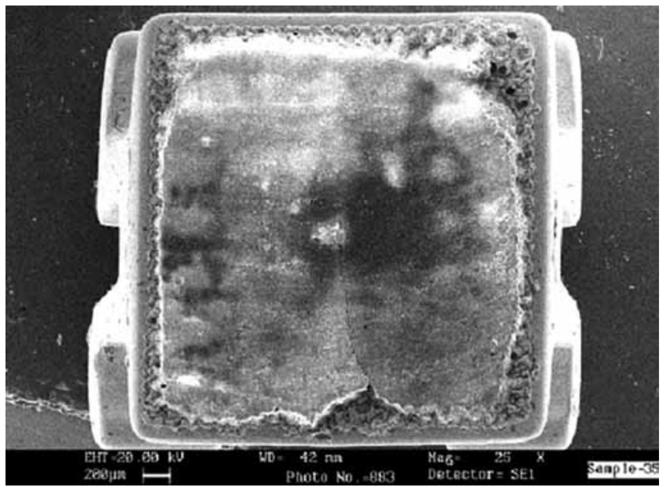

Fig. 4 : Laser-etched base bracket with adhesive on bracket base under SEM

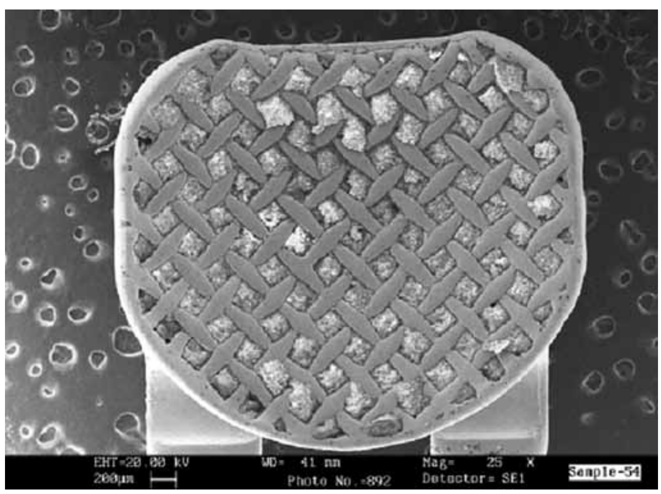

Fig. 3: Mesh base bracket with adhesive on bracket base under SEM

ENAMEL DETACHMENT INDEX SCORES

Enamel detachment, under bracket base was examined using energy dispersive X-ray spectrometer (Figs 3 and 4) and graded as per EDI (Table 7) Chi-square test was used to compare the pattern of EDI scores between two groups.

Test results showed that, laser-etched bracket had slightly more enamel detachment on the bracket base, when compared to mesh based bracket. However, it was observed that, there was no statistical significant difference between the two groups, with respect to EDI scores (p > 0.05) illustrated in Table 8.

Table 7: Enamel detachment index

Sl. no.	*Laser Base bracket*	*Sl. no.*	*Mesh base bracket*	*Sl. no.*	*Laser base bracket*	*Sl.* no.	*Laser base bracket*
1	0	16	0	31	1	46	0
2	0	17	1	32	1	47	0
3	2	18	0	33	1	48	1
4	0	19	2	34	1	49	0
5	1	20	0	35	1	50	0
6	0	21	1	36	1	51	0
7	1	22	0	37	1	52	0
8	1	23	0	38	1	53	0
9	1	24	0	39	1	54	0
10	0	25	1	40	1	55	0
11	1	26	1	41	1	56	1
12	1	27	0	42	1	57	1
13	0	28	0	43	0	58	0
14	1	29	1	44	0	59	0
15	0	30	1	45	0	60	1

Table 8: Comparison of enamel detachment index among different methods

	EDI			
Method	*0*	*1*	*2*	*Total*
Laser base	10 (33.3)	19 (63.3)	1 (3.4)	30 (100.0)
Mesh base	19 (63.3)	10 (33.3)	1 (3.4)	30 (100.0)
Total	29	29	2	60

$\chi^2 = 5.59$, DF = 2; p = 0.06 (Not significant)

DISCUSSION

There are numerous studies which intended to improve the bond strength by varying the acid etching technique, adhesive material, and bracket base design. Initially, studies were done to increase the bond strength by altering the etching time and acid concentrations. Results of these studies shows that, there was significant enamel loss occurring, which made the enamel surface more susceptible to decalcification.[24-30] Thus, in order to conserve the tooth structure, the focus was shifted in developing a stronger adhesive and a better bracket base design to increase the bond strength.

Several studies were done to study the influence of bracket base design.[31,32] It was found that, as the retentive surface area of the bracket bases were reduced for esthetic reasons, the base design and the surface morphology greatly influenced the bond strength.[33] Originally, metal brackets were fabricated with perforated backings that had 12 to 16 holes per bracket and the bonding resin would seep through these perforations and secure the bracket. The problem with this type of bracket was the decreased bond strength due to less number of retentive grooves to hold the adhesive.

Next common base design, which most orthodontists prefer to use, is the mesh based bracket.[34] These brackets are manufactured by using bracket dyes, the fine meshes are then pressed under heat to the foil having various thicknesses.

The problem with mesh based bracket was the presence of weld and presence of voids beneath the weld spots that exposed the area to marginal leakage and subsequent bond failure.[35-37] To overcome these problems, brazing was introduced. However, improper brazing, led to poor joining of mesh to base of the bracket. Even with all these problems, the mesh based bracket produced sufficient bond strength.

Several studies were done after this to improve the microscopic features of mesh based bracket by sand blasting,[14] photo etching,[13] silicoating[21] and laminating to improve the bond strength.[38-40] The problem with these type of bracket was the bond failure that commonly occurred at the interface of the mesh and the adhesive, leaving behind mesh wire and adequate amount of adhesive on the enamel surface that required to be cleaned.[6,18]

Next important improvement in the base design was the cast molded brackets, wherein the bracket and the base were made from a mold of single metal. This reduced the manufacturing difficulty and reduced the human errors. Bond failure with this was high due to inadequate retentive grooves because the release of these brackets from mold required the absence of under cuts.[12] A step forward in cast base design was the introduction of less expensive metal injection molding brackets.

Concomitant to the introduction of new bracket systems, laser-etching of bracket base was introduced. These laser beams evaporate and melts parts of the metal base leaving behind numerous hole shaped retentive grooves that increased the retentive mechanism.[19] Thus, this study was under taken to evaluate the bond strength, the site of bond failure, and the amount of enamel lost during debonding of laser-etched based bracket when compared to commonly used foil mesh based bracket.

In the first part of the study, the base area of laser-etched and mesh based bracket were evaluated with the help of traveling microscope. The average values of these brackets were 8.41 mm for laser-etched and 9 mm for mesh-based bracket. The reason to measure the bracket based area was to evaluate whether the surface area of these bracket bases have any influence on the bond strength. Studies have shown that surface area influence the bond strength.

In the second part of the study, out of 30 specimens from group I, 15 laser-etched and 15 mesh based brackets underwent tensile bond strength test at a crosshead speed of 6 mm/min using universal testing machine (TIRA) in tensile mode. The value of mean tensile bond strength of the groups tested at 6 mm crosshead speed showed that the laser-etched base bracket provided statistically significant (0.001) stronger tensile bond strength of mean 8.47 MPa (SD ± 0.84) , when compared with the simple foil mesh based bracket which had bond strength of mean 5.53 MPa (SD ± 0.89).

In the next part of the study, out of 30 specimens from group II, 15 laser-etched and 15 mesh based brackets were subjected to fatigue bond strength test to check the distortion of bracket base using the universal testing machine at a crosshead speed of 16 mm/min using the same universal testing machine (TIRA) in tensile mode. The results of the fatigue bond strength showed that the laser-etched based bracket had higher bond strength of mean 7.75 MPa (SD ± 0.79), when compared with the simple foil mesh base brackets that had bond strength of mean 5.17 MPa (SD ± 1.15).

Reynolds[9] in his study has suggested 5.9 to 7.8 MPa as the optimal bond strength required for bonding of brackets to enamel. The results of this bond strength test show that laser-etched base bracket has more than optimal bond strength required for successful bonding. Thus, it is clear that laser-etched base bracket can successfully be used for bonding, with less chance of unexpected debonding occurring during treatment.

According to O'Brien KD, Watts DC and Read MJE[17] the amount of residual debris following debonding is not related to bond strength. Numerous studies were conducted to evaluate the means of ensuring a better mechanical interlocking and the effective resin penetration into the bracket base. The results of these studies indicated that, for effective resin penetration into the bracket base, is governed by bracket base design. Therefore, in the next part of the study all the debonded brackets were examined under stereomicroscope to evaluate the adhesive remaining on the bracket base using the index developed by Artun and Bergland.[22]

Finding of the ARI indicated that the laser-etched base bracket had ARI score of 3 in 60% of the bracket base indicating that the greater part of the adhesive remained on the base of these debonded brackets. In comparison, when the mesh base bracket was subjected to the ARI index, it had maximum number of the bracket base with a score of 0, indicating that the large part of the adhesive remained on the enamel surface. Thus, when the ARI scores between the laser-etched base bracket and the mesh base bracket were compared it was evident that the laser-etched based bracket had bond failure in the enamel-adhesive interface and the mesh based bracket had bond failure in the bracket-adhesive interface.

Thus, when we summarize the amount of enamel loss caused due to various cleaning procedure, it was clear that substantial amount of enamel was lost, when the site of bracket failure was at the interface of bracket and adhesive, which left large amount of adhesive to be cleaned.

In order to evaluate the amount of enamel remnants present on the bracket bases, at the end of debonding, the specimens were subjected to energy dispersive X-ray spectrometer (EDXS). All the debonded bracket bases were examined under EDXS to check the presence of calcium, phosphorous and silica.

The mapping of the bracket base area under EDXS showed that less than 10% of enamel detachment (EDI score of 1) was observed as a perikymatic impression on the bracket base with a thickness of less than 1.5 µm on both the types of the bracket bases. This is similar to the findings of Olivier Sorel.[19]

From this preliminary study, it was evident that laser-etched base bracket have a superior bond strength, than the optimal bond strength required for successful bonding of brackets to the enamel surface. This study also showed that, bond failure for the laser-etched base bracket, occurred at the interface of enamel-adhesive, indicating, less chair side time would be required for removal of adhesive. This was one of the major advantages, as there was substantial reduction in enamel damage caused due to debonding clean up procedure.

Finally, laser-etched base bracket also showed that, less than 10% of enamel detachment occurring during debonding which was statistically not significant.

The future trend and focus mainly lies on conserving the enamel, further studies should be carried out using laser-etched base bracket and crystal bonding technique, to prevent enamel loss caused due to acid-etching.

SUMMARY AND CONCLUSION

With the concept to developing superior bond strength, many manufacturers have come up with various bracket base designs. One such development is the laser-etched based bracket, which the manufacturer claims to be superior to the other bracket base designs. Whenever a new bracket is introduced, bond strength of these newly introduced brackets is the center for its clinical success,

Based on the recorded data and the statistical analysis, the following conclusions were drawn:

- The laser-etched bracket base have superior bond strength than the simple foil mesh bracket
- The bond failure for laser-etched base bracket was located at the enamel—adhesive interface, with an ARI score of 3 obtained in 60% of the specimens
- The bond failure for mesh-based bracket was located at the bracket base—adhesive interface, with an ARI score of 0 obtained in 65% of the specimens

- A small area of enamel detachment with a EDI score of 1 was observed in both the laser-etched bracket base and the simple foil mesh-based bracket which was not statistically significant.

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