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Evaluation of Shear Bond Strength of Various Orthodontic Bracket Base Designs – An In Vitro Study

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ABSTRACT

Background: To determine the influence of various bracket base designs on bond strength and debond interface, 3 types of metal interlock brackets (Gemini, Mini Diamond and Sapphire) of different sizes and with different base designs were evaluated. **Methods**: 60 maxillary premolars were collected from patients undergoing orthodontic treatment. Sixty Pre-adjusted edgewise brackets of MBT 0.022 prescription were used for the study. The brackets were bonded with the same adhesive and debonded with a Universal Testing Machine. The bracket bases were examined under Scanning Electron Microscope. **Results**: Values of bond strength with different commercially available brackets is different even after using the same adhesive. **Conclusion**: Mini Diamond brackets had the highest mean shear bond strength followed by Gemini and Sapphire brackets.

Keywords: Shear bond strength, bracket base, mesh, debond.

INTRODUCTION

Various factors have an influence on the bond strength of orthodontic brackets including the size and design of the bracket base.[1-11] The bracket must be able to deliver orthodontic forces and be able to bear masticatory loads, and at the same time be aesthetically pleasing and should be able to be removed easily at the end of active treatment.[11] A mechanical undercut in the bracket base provides a place in which adhesive can extend before polymerization of resin starts to occur.[11] In most of the cases retention of metal brackets is achieved with a fine brazed mesh. In other cases the bases might have a milled undercut or the bases may be sandblasted, chemically etched, or sintered with porous metal powder. With a mechanical interlock and etching time of 15 seconds bond failure occurs at the resin bracket base interface, within the resin itself, or between the resin and enamel. However, there was relatively greater bond failure between the resin and bracket because of stress concentrations and defects in the resin film.[1,12,13] So the need of the hour is a bracket which has a good retentive bonding between the resin and metal base. The size of the base and the base design might affect bond strength. The purpose of this study was to determine the bond strength of 3 types of brackets, each representing a unique combination of base design and size.

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MATERIALS AND METHODS

Teeth A total of 60 maxillary premolars were collected from patients (9-20 years of age) undergoing orthodontic treatment. The teeth were washed and stored in physiologic saline solution in a closed plastic box; they were used for testing within 3 months. The criteria of tooth selection were as follows: (1) the crown was grossly perfect with no defect, (2) the tooth had never been pre-treated with a chemical agent, such as hydrogen peroxide or formalin, and (3) the contour of the labial surface of the tooth crown was adapted to the base of the bracket before bonding. The teeth were randomly divided into 3 groups of 20 teeth each. The teeth were embedded in self cure acrylic cubes of 1× 1× 3 cubic centimetre dimensions so that the teeth do not move during shear bond testing.

Brackets Sixty Pre-adjusted edgewise brackets of MBT 0.022 prescription were used for the study. The brackets consisted of three different manufacturers with brackets of each manufacturer forming a separate study group [Table 1]. In each group a total of 15 brackets were taken for testing shear bond strength whereas 5 brackets were used for observation under scanning electron microscope.

The buccal surface of each crown was polished with pumice powder water paste containing no fluoride or oil for 10 seconds and then rinsed with abundant water spray and dried with air spray. The buccal surface of the enamel was etched for 15 seconds with 30% phosphoric acid solution.[12,13] The bonding agent (Transbond, 3M) was applied to the central surface of the pretreated crown and bracket base. Once the bracket was in the correct position, excess composite resin was removed from the margin of the bracket with a dental probe. All specimens were completed within 24 hours. The treated specimens were incubated in a 37°C water bath for 24 hours and then tested on Universal Testing Machine (Llyod) with a tensile force of 2 mm/min crosshead speed. Details of these procedures were described in a previous study.[12] Bond strength and debonded interface distribution were recorded. Means and standard deviations were determined and analysed by 1- or 2-way analysis of variance (ANOVA). The Scheffe´ test was used to further identify statistically significant differences.

Table 1: Type pf bracket used

Group	Brackets	Base	Guaze	Area	Manufacturer
1	Gemini	Microetched foil mesh	80	9.82 mm sq.	3m unitek USA
2	Sapphire	Foil mesh	80	11.22 mm sq.	Modern orthodontics India
3	Mini-diamond	Optimesh	100	9.32 mm sq.	ORMCO corporation USA

After debonding of the brackets the enamel of each tooth was examined under 10X magnifying lens. The amount of adhesive on enamel on each tooth was calculated as per ARI (Adhesive Remanant Index) given by Artun and Bergland.[14]

Table 2: ARI- Adhesive Remanant Index

SCORE 0	No adhesive left on tooth.
SCORE 1	Less than half adhesive left on tooth.
SCORE 2	More than half adhesive left on tooth.
SCORE 3	All adhesive left on tooth.

Stastical analysis:

The results of shear bond strength of each group were subjected to SPSS 20 version (Statical Package for Social Sciences). Mean, standard deviation, maximum and minimum values were calculated for each group. One way ANOVA was used to find out if significant differences were present in different groups. Kruskal-Wallis test was done to detect any significant differences in the experimental groups ARI's. A p value of less than 0.05 was considered significant.

RESULTS

Highest mean bond strength was seen in Mini Diamond series followed by Gemini group which was followed by Sapphire [Table 3]. Statistically significant difference in bond strength [Table 4] and adhesive remnants [Table 5] was seen in different groups. The Gemini brackets achieved the highest modulus followed by Mini Diamond and Sapphire. Mesh gauze size provided by the manufacturer and mesh gauze size calculated by SEM was not identical in any type of bracket. There was a significant difference between the two with highest difference seen in case of Sapphire brackets.

Table 3: Shear bond strength of all groups

Sample	Gemini	Sapphire	Mini Diamond
1	18.99	11.4	24.1
2	16.22	12.2	22.3
3	21.2	12.3	21.4
4	24.4	6.7	19.2
5	22	14.1	17.8
6	17.1	13.2	15.9
7	24.3	15.1	18.8
8	19	12.7	22.3
9	18.8	11.9	19.3
10	17.2	6.2	20.7
11	16.6	8.7	19.4
12	18	12.9	21.4
13	17.4	13	23
14	19.1	14.1	24.1
15	21.3	5.9	19.5
Mean	19.42	11.36	20.74
SD	3.58	2.47	7.83
Maximum	24.4	15.1	24.1
Minimum	16.22	5.9	15.9
ANOVA	p=0.000		

Table 4: Post-hoc multiple comparisons using Scheffe's test.

Groups	Sapphire	Mini Diamond
Gemini	0.088 (NS)	1.0000 (NS)
Sapphire		0.028

NS = Not Significant

Table 5: ARI Scores

Group	n	Score 0	Score 1	Score 2	Score 3	Kruskal-Wallis
Gemini	15		2	5	8	P=0.000
Sapphire	15		6	7	2	
Mini Diamond	15		5	2	8	

DISCUSSION

In this study only one type of adhesive was used to make sure that whatever variation is seen in bond strength is due to differences in mesh design and surface area of the base. The results of this study indicate that the relative bonding strength for the Mini Diamond bracket was 20.74 MPa. This bracket has a relatively large base with many circular concavities that allow air to escape so that the composite resin can penetrate into the concave surfaces. This resulted in better retention and relatively less de-bonding between the bracket and resin (35.3%) than occurred with other bracket base designs.

For in vitro bond testing procedure the protocol of Fox 14 was used in this study. Debonding was carried out on Llyod universal testing machine and at a cross head speed of 2 mm per minute. The cross head speed suggested by Fox was 0.1 mm per minute whereas that suggested by Klocke and Nieke varied between 0.1 and 5 mm per minute.

Among all the study groups Mini Diamond achieved the highest mean bond strength. It was closely followed by Gemini. Whereas Sapphire brackets showed the lowest mean Shear Bond Strength which appears to be influenced by defective mesh configurations. There were broken mesh wire in the bracket bases which prevented adequate mechanical interlocking.

In the present study the area of the bracket bases ranged from 9.32 to 11.22 square mm. The size of the bracket bases does not seem to influence the mean bond strength as sapphire brackets in spite of having large area could not perform well in the area of bond strength due to faulty bases. The wire diameter and mesh spacing determine the number of openings per unit area of the bracket base.[15] The free volume between the mesh and the base will also affect the penetration of resin, the escape of air, and the effectiveness of bonding. The Dentaurum, Leone, TP Orthodontics, and Ormco brackets have mesh-type bases, with mesh spacing that ranges from relatively large (Dentaurum, 5.1×10-2 mm2) to small (Ormco, 2.9×10-2mm2). The 60, 80, and 100 mesh bases all have different mesh spacings. Knox et al reported that the bondstrength of the 100-mesh size with Concise bonding agent was greater than that of 60- and 80-mesh sizes with statistically significant differences. The bonding strength of Dynalock showed no statistically significant differences from 60-, 80-, and 100-mesh bases.

A higher percentage of open area provides better penetration of the adhesive particles thus enhancing mechanical interlocking between the base and the adhesive leading to improved bone strength and lesser bond failures. For Mini Diamond highest (55.5) open area percentage and for Sapphire lowest (35.1) open area percentage was observed. The open area percentage for Gemini brackets was 42.1. The Sapphire brackets with the finest mesh and lowest open area percentage was considered least reliable among all study groups. A lower percentage of open area diminishes the penetration of adhesive particles.

For Sapphire brackets the maximum bond failures occurred at the bracket resin interface. The obvious reason for this would be faulty mesh framework leading to stress concentration at the mesh resin interface making it prone to early bond failures. Poor penetration of the resin in the mesh leads to air entrapment at the adhesive interface leading to oxygen inhibition of polymerisation and a layer of uncured resin. For Gemini and Mini Diamond brackets the maximum bond failures occurred at the bracket resin interface but the threshold for this failure was much higher than with the Sapphire brackets.

The study thus proved that the values of bond strength with different commercially available brackets is different even after using the same adhesive.

CONCLUSION

1. The size and design of a bracket base can affect bond strength.
2. The Mini Diamond bracket produced greater bond strength than the Gemini and Sapphire, with their mesh bases.
3. Among the brackets with mesh-type bases, the higher the open area percentage, the greater the bond strength.
4. Most debonding interfaces are between bracket and resin.

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