Original Article

Comparison of Shear Bond Strength of RMGI and Composite Resin for Orthodontic Bracket Bonding

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Abstract

Objective: The aim of this study was to compare the shear bond strength (SBS) of resin modified glass ionomer (RMGI) and composite resin for bonding metal and ceramic brackets.

Materials and Methods: Eighty-eight human premolars extracted for orthodontic purposes were divided into 4 groups (n=22). In groups 1 and 2, 22 metal and ceramic brackets were bonded using composite resin (Transbond XT), respectively. Twenty-two metal and ceramic brackets in groups 3 and 4, respectively were bonded using RMGI (Fuji Ortho LC, Japan). After photo polymerization, the teeth were stored in water and thermocycled (500 cycles between 5° and 55°). The SBS value of each sample was determined using a Universal Testing Machine. The amount of residual adhesive remaining on each tooth was evaluated under a stereomicroscope. Statistical analyses were done using two-way ANOVA.

Results: RMGI bonded brackets had significantly lower SBS value compared to composite resin bonded groups. No statistically significant difference was observed between metal and ceramic brackets bonded with either the RMGI or composite resin. The comparison of the adhesive remnant index (ARI) scores between the groups indicated that the bracket failure mode was significantly different among groups ($P<0.001$) with more adhesive remaining on the teeth bonded with composite resin.

Conclusion: RMGIs have significantly lower SBS compared to composite resin for orthodontic bonding purposes; however the provided SBS is still within the clinically acceptable range.

Key words: Shear bond strength; Bracket; RMGI; Composite resin

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INTRODUCTION

The acid etch technique is the most commonly used method for orthodontic bracket bonding. However, this technique imposes the risk of demineralization of enamel adjacent to brackets and requires drying of enamel surface; which is important in increasing the bond strength of brackets [1, 2].

Glass Ionomer cements (GICs) were initially introduced to dentistry by Wilson and Kent and to orthodontics by White [3]. GICs possess many properties such as forming chemical bonds with enamel, dentin, metal and plastic through the affinity of calcium in tooth structure to carboxylate groups in the reacted GIC. Because of this unique ability, the GICs do not require a completely dry bonding field [3, 4]. GICs release fluoride within the period of at least 12 months and also have the ability of fluoride recharging from fluoride-containing materials such as toothpastes. This may protect enamel from decalcification [5]. Despite their advantages, GICs have some drawbacks for orthodontic bonding namely weak bond strength [6], high rate of bracket detachment [7] and poor early mechanical properties [8]. Addition of small amounts of light activated resin was found to be effective for improving the properties of GICs [9]. The resultant material is known as resin-modified glass ionomer (RMGI) introduced in 1988 [10]. Similar to GICs, RMGIs have fluoride release and rechargability but are less susceptible to moisture and dehydration during setting and demonstrate better physical properties [11]. The bond strength of RMGIs to enamel ranges from 5.4 to 18.9 MPa reported in the orthodontic literature [12- 14].

Nowadays, many adults are interested in orthodontic treatments and prefer aesthetic appliances such as ceramic brackets. Ceramic brackets chemically bond to enamel producing very high bond strength. These brackets are not distortable; thus, impose a high risk of enamel fracture during debonding. However, most manufacturers have weakened or eliminated the process of chemical bonding of ceramic brackets [15]. Regarding metallic brackets, the important question is whether their bond strength to GICs is too weak to withstand the applied forces during orthodontic treatment while with ceramic brackets the concern is whether their bond to GICs is too strong and problematic for debonding [16].

In a study by Haydar et al, [17] (1999) the shear bond strength of light-cured composite resins, a light- cured glass ionomer cement and a light-cured compomer used with metal and ceramic brackets were compared and ARI scores were evaluated. They reported that ceramic brackets bonded with either of the tested materials had significantly higher shear bond strength compared to metal brackets. Regarding metal brackets, bonding with light-cured composite leads to higher bond strength in comparison with light-cured glass ionomer cement (LCGIC) and compomer.

Usyal *et al,* [18] in their study on the shear bond strength of metal and ceramic brackets bonded by means of self etching primers (SEPs) concluded that the shear bond strength of Transbond Plus self etching primer was significantly lower than of conventional acid etch groups. The aim of this in-vitro study was to compare the shear bond strength of RMGI and composite resin for metal and ceramic bracket bonding.

MATERIALS AND METHODS

In this experimental lab trial study, 88 human premolars extracted for orthodontic purposes without caries, fractures, wears or developmental defects were collected and immersed in 0.5% sodium hypochlorite for disinfection and stored in normal saline before the onset of study. Two bonding agents, a composite resin (Transbond XT) and a RMGI (Fuji Ortho LC, Japan) and 44 stainless steel as well as 44 ceramic premolar brackets (both 0.018 inch slot size, standard edgewise brackets) were used in this study. The teeth were randomly divided into 4 groups of 22 teeth as follows:

Group 1: Stainless steel brackets bonded with composite resin.

Group 2: Ceramic brackets bonded with composite resin.

Group 3: Stainless steel brackets bonded with RMGI.

Group 4: Ceramic brackets bonded with RMGI.

Labial surfaces of teeth were cleaned with a rubber cup and sprayed with water. The procedure for group 1 and 2 included application of 37% phosphoric acid etchant on the labial surface of teeth for 30 seconds followed by rinsing and drying by an oil and moisture free air. Then, adhesive coated brackets were placed on the labial surface with gentle pressure.

The teeth in groups 3 and 4 were conditioned with the application of 10% acrylic acid to the labial surface for 20 seconds, rinsed for 15 seconds and dried with oil and moisture free air. RMGI was prepared according to the manufacturer's instructions and placed on the brackets. Excess adhesives were removed with a sharp scaler. The adhesive coated brackets were placed on the teeth surfaces and light cured for 10 seconds each at the occlusal, gingival, mesial and distal sides by an LED (Dentin Faraz) light source with a light intensity of 500 mW/cm^2 (controlled by a radiometer). The teeth were mounted in a block of self-curing acrylic resin at the level of 1mm below the cemento-enamel junction, which stabilized specimens in an Instron testing machine.

The teeth were stored in normal saline and thermocycled in water between 5° and 55° for 500 cycles (30 seconds in 5° water and 15 seconds out of water and again 30 seconds in 55° water and 15 seconds out of water).

After a week, the shear bond strength was evaluated by an Instron (Dartech, England) testing machine with a crosshead speed of one mm/minute until bracket failure. After the debonding procedure, all the teeth and brackets were examined under a stereomicroscope at 10x and 40x magnifications to assess the amount of residual adhesive remaining on the enamel and the sites of bond failure in the enamel, resin and bracket base. The adhesive remnant index (ARI) introduced by Bishara [19] was used to evaluate the amount of adhesive left on the labial surface of teeth.

The criteria for evaluation were:

Score 1: All the adhesive remained on teeth.

Score 2: More than 90% of the adhesive remained on teeth.

Score 3: Between 10% to 90% of the adhesive remained on teeth.

Score 4: Less than 10% of the adhesive remained on teeth.

Score 5: No adhesive remained on teeth.

Data were analyzed using SPSS software. Comparisons were made using two-way ANOVA.

RESULTS

The mean value of shear bond strength in groups 1, 2, 3 and 4 was 20.03±4.44, 22.52±6.39, 6.63±3.44 and 8.69±3.12, respectively.The mean shear bond strength of the four groups is presented in Table 1.

The bond strength of composite resin was significantly greater than RMGI. Additionally, the bond strength of ceramic brackets was higher than stainless steel brackets.

The maximum and minimum SBS values were observed in group 2 (22.52±6.39) and group 3 (6.63±3.44), respectively.

In order to evaluate the main effects and interactions between the bracket type and bonding material, two-way ANOVA was used; which showed no significant interaction between the variables (Table 2). The amount of residual adhesive on the enamel surface evaluated by a stereomicroscope and the frequency of each score are reported in Table 4. The results showed a higher frequency of ARI score 3 in groups 1 and 2 and score 4 in groups 3 and 4. The mode of failure was mostly adhesive in composite resin bonded groups (1 and 2) and at the enamel- adhesive interface in RMGI bonded groups (2 and 3).

DISCUSSION

GICs form ionic bonds between the negatively charged carboxylate groups in the glass ionomer and the positive calcium ions on the tooth surface. The preparation protocol for GICs is to clean the enamel surface but not demineralizing it [10, 20] by using a weak acid such as polyacrylic acid.

Table 1. The mean shear bond strength values in the four groups. Group 1: stainless steel brackets + composite resin; group 2: ceramic brackets + composite resin; group 3: stainless steel brackets + RMGI; group 4: ceramic brackets + RMGI.

Group	N	Mean|(MPa)	SD	Min	Max
Group 1	22	20/03	4/44	13/46	30/45
Group2	22	22/52	6/39	11/72	33/01
Group 3	22	6/63	3/44	2	17/63
Group 4	22	8/69	3/12	1/32	33/01

Table 2. The results of two-way ANOVA. Factor 1: bonding material, Factor 2: bracket type.

Source	DF	SS	MS	F	P-value
Factor 1	1	4532.02	4532.02	223.26	0.000
Factor 2	1	54.42	54.42	2.68	0.105
Interaction	1	0.06	0.06	0.00	0.958
Error	84	1705.16	20.30		
Total	87	6291.65			

Table 3. The frequency distribution of ARI scores in the four groups. Group 1: stainless steel brackets + composite resin; group 2: ceramic brackets + composite resin; group 3: stainless steel brackets + RMGI; group 4: ceramic brackets + RMGI.

*ARI	Group 1		Group 3		Group 2		Group 4	
	N	%	N	%	N	%	N	%
1	1	4/5	2	9/1	0	0	0	0
2	3	12/6	1	4/5	1	4/5	2	9/1
3	15	68/2	13	59/1	3	13/6	2	9/1
4	2	9/1	4	18/2	13	59/1	12	54/5
5	1	4/5	2	9/1	5	22/7	6	27/3
plus	22	100	22	100	22	100	22	100

Phosphoric acid etching is not appropriate for GICs due to their demineralizing effect on the bonding surface and subsequent reduction in bond strength [20]. Based on the previous data documenting the poor properties of GICs as orthodontic cements, they are not completely accepted for use by the orthodontic community [5, 21-22]. However, some studies have reported that RMGIs may be suitable for bonding orthodontic brackets [23, 24].

Ceramic brackets are increasingly used because of their superior aesthetic properties. The problem with ceramic brackets is their high bond strength; which can result in enamel fracture during debonding. Additionally, ceramic brackets are very brittle and their dimensional change before fracture is less than 1%; therefore debonding forces may result in fracture of the ceramic brackets. Because of the large amount of bracket material remaining on the teeth, the clean up process requires the use of abrasive burs and may result in enamel surface loss [16].

Reynolds [25] suggested that minimum bond strength of 5.9-7.8 MPa is required for bracket bonding to enamel surfaces; while Lopez *et al* [26]. showed that the shear bond strength of 7 MPa provides clinically successful bonding.

Retief in his study revealed that enamel fracture could occur with bond strengths as low as 13.5 MPa [27]. Bond strength values of the brackets in groups 1 and 2 in this study were greater than the minimum requirement reported by Retief [27] and subsequently can result in enamel fracture during debonding. Thus, such high bond strength should be reduced for example by bending bracket wings toward each other to minimize the risk of enamel fracture. The bond strengths of brackets in groups 3 and 4 of the present study are in the range of 5.9 to 7.8 considered by Reynolds [25] and therefore the bond strength provided by RMGIs is adequate for routine clinical use. The SBS in group 4 was greater than the rate suggested by Lopez *et al,* [26] and may be associated with higher clinical success; additionally, fluoride release from RMGIs makes them a more suitable material than composite resins for orthodontic bracket bonding. In our study, the SBS of orthodontic brackets bonded with composite resin was higher than that of RMGI; which is similar to the findings of Voss *et al* [28], Komori *et al* [29], Fajen *et al,* [30] and Haydar *et al,* [17]. The SBS of ceramic brackets was found to be higher than that of stainless steel brackets; which is in accordance with the results of Uysal *et al* [18] and Haydar *et al* [17].

The highest and the lowest values of SBS were displayed in group 2 (22.52± 6.39 MPa) and group 3 (6.63± 3.44 MPa), respectively.

In a study by Haydar *et al,* [17] the shear bond strengths of light-cured composite resins, a light-cured glass ionomer cement and a light-cured compomer used with metal and ceramic brackets were compared. The shear bond strength of ceramic brackets was significantly higher than that of metal brackets. The highest value of SBS (20.17 MPa) belonged to ceramic brackets bonded with light-cured composite resins and the lowest SBS (4.45 MPa) belonged to metal brackets bonded with light-cured glass ionomer cement. Their findings are in accordance with those of the present study. In our study, the SBS of group 1 was 20.03±4.44 MPa; which was similar to the findings of Rix *et al* [21] but higher than the SBS values reported by Movahed *et al,* [31] and Bishara *et al* [32].

In analyzing different parameters influencing the results of this study, it should be considered that in studies done by Movahed *et al* [31] and Bishara *et al* [32] the light curing time was half the time in our study and they used Transbond Plus self etching primer. Since the application of self etching technique compared to conventional acid etching results in less adhesive penetration into the enamel, the lower SBS is expected in groups bonded with self etching technique. In a study done by Khosravanifard *et al,* [33] the light-curing time was 55 seconds; which was greater than the 40 seconds curing time used in the present study according to Forughmand *et al* [34]. Increasing the curing time results in higher SBS; however the manufacturer's instruction for curing time is 20 to 40 seconds. Bond failure and debonding are important problems in fixed orthodontic treatments. In the current study, it was found that brackets bonded by means of Fuji Ortho LC differed from those bonded using Transbond adhesive in the sites of bond failure. The results showed a higher frequency of ARI score 3 in brackets bonded with Transbond and score 4 in brackets bonded with Fuji Ortho LC.

Bond failure for brackets bonded with Fuji Ortho LC occurred mostly at the enamel-adhesive interface which might be the result of mechanical retention of the bracket base or chemical bonding between the ceramic bracket and RMGI; while brackets bonded with Transbond typically failed at the bracket-adhesive interface.

Bond failure at any of the mentioned interfaces has its own advantages and disadvantages. For instance, bond failure at the bracket-adhesive interface is advantageous because it leaves an intact enamel surface; however removing residual adhesive is time consuming and imposes the risk of enamel damage. On the other hand, bond failure at the enamel-adhesive interface leaves less residual adhesive remnants but the risk of enamel surface damage is increased. Bond failure at the enamel-adhesive interface leaves less adhesive remnants on the enamel surface and therefore decreases the risk of enamel damage during adhesive removal but imposes a higher risk of enamel damage during debonding; although because of lower SBS compared to Transbond composite, the risk of enamel damage during debonding is low as well.

CONCLUSION

RMGIs can provide sufficiently high shear bond strength for bonding of metal and ceramic brackets.

In cases with aesthetic demands and use of ceramic brackets, RMGIs are preferred since they provide adequate SBS and are associated with lower risk of enamel damage during debonding.

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