IDJ Iraqi Dental Journal Volume:35 / Issue:1 / 2013

In Vitro Evaluation of the Effect of Thermocycling on the Shear Bond Strength of Light-Cured Composite and Resin Modified Glass Ionomer Cement Using Different Orthodontic Brackets (In vitro Comparative study)

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ABSTRACT

Background: This study was conducted to investigate and compare the effects of thermocycling on the shear bond strength of two light cured orthodontic bonding materials, namely composite and resin-modified glass ionomer cement that used to bond stainless steel and Sapphire brackets on human teeth, and to determine the type of bonding failure of these materials.
Materials and Methods: Eighty extracted human premolars were selected and randomly divided into two equal groups each with 40 teeth according to the brackets types. Both groups were subdivided into four groups (n = 10) two of these subgroups bonded with composite one control and the second thermocycled and the other two subgroups bonded with resin-modified glass ionomer cement also one control and the second thermocycled. The sample were stored in water at 37º C for 24 hours, then the control groups were tested while the study groups were thermocycled between 5 º C and 55 º C for 500 cycles. The samples were tested for shear bond strength using an Instron universal testing machine. For adhesive remnant index, the enamel surface and bracket base of each tooth were inspected under magnifying lens (20X) of a stereomicroscope.
Results and Conclusions: The shear bond strength of light-cured composite is higher significantly than resin-modified glass ionomer cement. Thermocycling decreases the shear bond strength of the sapphire brackets bonded with composite significantly by 60.16%. The most predominant sites of bond failure are within the adhesive itself and between the adhesive and the enamel.

KEYWORDS: Shear bond strength, Thermocycling, Resin-modified glass ionomer cement, Composite.

INTRODUCTION

After the introduction of acid etch technique and using composite as orthodontic adhesive, the problems of teeth decalcification, gingival inflammation, caries and many problems associated with banded fixed orthodontic appliances were reduced but decalcification around the orthodontic brackets remains the major problem until the introduction of glass ionomer cement (GIC) which has less harmful effect of dental enamel, release fluoride and has good adhesive properties. Also, GIC has the ability to absorb fluoride from topical fluoride applications. This feature allows it to act as a long-term fluoride releasing agent.

Antonucci *et al*.[1] introduced resin-modified glass ionomer cements (RMGICs) which set through a combination of acid–base reaction and photochemical polymerization.

"Resin-modified" refers to all cements in which the acid–base reaction of true glass-ionomer cements is supplemented by a polymerization reaction.[2]

In their simplest form, these are glass ionomer cements (GICs) with the addition of a small quantity of a resin such as hydroxyethyl methacrylate (HEMA) or Bis – GMA in the liquid as a co-solvent to avoid phase separation of the resin from the glass-ionomer components.[3,4]

The fundamental acid/base curing reaction is supplemented by a second curing process, which is initiated by light or chemical. These products are considered to be dual – cure cements if only one polymerization mechanism is used; if both mechanisms are used, they are considered to be tri – cure cements. These new materials are called as resin modified glass ionomer cements or hybrid ionomers. These materials are defined as hybrid materials that retain a significant acid – base reaction as part of their overall curing process.[5] Actually, resin modified GIC lies between pure resins composite and pure GIC.[6]

Arici and Arici[7] investigated the effects of thermocycling between 5ºC and 55ºC for 200 and 20,000 cycles, before testing, on the shear bond strength of chemically cured resin-modified glass ionomer cement in comparison with no-mix composite used to bond metal brackets. They found that there were very high significant differences between the mean shear bond strengths of the groups. For the resin-modified glass ionomer cement groups, the predominant bond failure site was at the bracket-adhesive interface.

In Iraq, four studies[8-11] evaluated the shear bond strength of resin-modified glass ionomer cement but no study evaluated the effect of thermocycling on the shear bond strength except for one study that evaluate the thermocycling on the shear bond strength of two types of self- etch primers;[12] so this *in vitro* study was carried out to investigate the effects of thermocycling on the shear bond strengths of a light cured resin-modified glass ionomer cement used for bonding of orthodontic brackets and to compare this bonding agent with a light cured conventional composite resin. The bond failure sites were also investigated.

MATERIALS & METHODS

Teeth

Eighty freshly extracted human premolars were collected and stored in a solution of 0.1% (weight/volume) thymol. The criteria for tooth selection included intact buccal enamel that had not been subjected to any pretreatment chemical agents, e.g. hydrogen peroxide, with no cracks due to the pressure of the extraction forceps, and no caries.

Retentive wedge shaped cuts were made along the sides of the roots of each tooth to increase the retention of the teeth inside the self-cured acrylic blocks. Each tooth was fixed on a glass slide in a vertical position using soft sticky wax at the root apex, so that the middle third of the buccal surface was oriented to be parallel to the analyzing rod of the surveyor. This kept the buccal surface of tooth parallel to the applied force during the shear test.[13] Then the two L-shaped metal plates, were painted with a thin layer of separating medium (Vaseline) and placed opposite to each other in such way to form a box around the vertically positioned tooth with the crowns protruding. After that, the powder and liquid of the self cured acrylic were mixed and poured around the tooth to the level of the cemento-enamel junction of each tooth.[14] After setting of the self cured acrylic resin, the two L-shaped metal plates were removed, the sticky wax used for fixation of tooth in the proper orientation removed too and the resulting holes filled with self cure acrylic. Slight adjustment of the acrylic blocks was done using the portable engine to adjust the acrylic block to make it fit properly in the testing machine. After mounting, the specimens were color coded and stored in normal saline solution with thymol to prevent dehydration until bonding.[15]

Brackets

Two types of 0.022" MBT orthodontic brackets were used in this study: Stainless-steel brackets {Mini-sprint®} from Forestadent Co., Germany and Sapphire brackets {Perfect SB (clear®)} from Hubit Co., South Korea with base surface area 8.92mm^2 and 12.807mm^2 respectively.

The selected eighty teeth were randomly divided into two main groups 40 teeth of each on the basis of type of brackets: Group A: Stainless-steel brackets {Mini-sprint®} and Group B Sapphire brackets {Perfect SB (clear®)}. Both groups were subdivided into four groups (n = 10) according whether thermocycled or not:

- Group (AI): stainless steel brackets bonded with light cured composite and stored in water at 37ºC for 24 hours.
- Group (AII): stainless steel brackets bonded with light cured composite and thermocycled for 500 cycles.
- Group (AIII): stainless steel brackets bonded with light cured RMGIC and stored in water at 37ºC for 24 hours.
- Group (AIV): stainless steel brackets bonded with light cured RMGIC and thermocycled for 500 cycles.
- Group (BI): Sapphire brackets bonded with light cured composite and stored in water at 37ºC for 24 hours.
- Group (BII): Sapphire brackets bonded with light cured composite and thermocycled for 500 cycles.
- Group (BIII): Sapphire brackets bonded with light cured RMGIC and stored in water at 37ºC for 24 hours.
- Group (BIV): Sapphire brackets bonded with light cured RMGIC and thermocycled for 500 cycles.

Bonding and Thermocycling

The teeth were cleansed and then polished with pumice slurry and rubber prophylactic cups for 10 seconds then thoroughly washed and dried.[16]

For the composite, (according to the manufacturer's instructions) 37% phosphoric acid gel was applied for 30 seconds, washed with air water spray for 20 seconds and then dried with oil/ moisture-free air until the buccal surface of the etched tooth appeared chalky white in color. Thin uniform coat of Resilience® sealant (Ortho technology Co., USA) were applied by brush on each tooth surface to be bonded. Small increment of Resilience® adhesive paste (Ortho technology Co., USA) then applied onto the bracket back using flat ended instrument.

For the RMGIC (GC Fuji Ortho LC, GC Corporation/Japan), also according to the manufacturer's instructions, the standard powder to liquid ratio was 3.0g/1.0g was mixed (1 level large scoop of powder to 2 drops of liquid) which was mixed by dividing the powder into two equal parts; the first part was mixed with all the liquid and mix for about 10 seconds. Then the other part of powder was incorporated and mixed thoroughly for an additional 10-15 seconds (total mixing is 25-30 seconds) the final mixture was having creamy honey-like consistency. Immediately after applying the adhesive to the bracket base, the bracket was placed gently onto the centre of the labial surface using a clamping tweezers.

A load of about 300g was attached to the vertical arm of the surveyor to standardize the pressure applied on the brackets during bonding to ensure seating under an equal force and to ensure a uniform thickness of the adhesive and prevent air entrapment which may affect bond strength.(17) The excess then removed from around the bracket with dental probe.

Flash Max 2 light cure unit (CSM dental Aps, Denmark) uses a 15 Watt diode. This super LED has an optical out-put well above 4.000 mW/cm^2 was used to cure the two types of adhesives. Six seconds; three seconds from mesial and three seconds from distal sides used to cure the adhesives with a minimum separation distance (1-2) mm. Every tooth was left undisturbed for 30 minutes to ensure complete polymerization of adhesive material.(18)

After bonding, all samples stored in water at 37ºC for 24 hours. The control group tested after that while the study samples were thermocycled between 5°C and 55°C for 500 complete cycles. The thermocycling was done manually following the recommendation of the international organization for standardization (ISO/TS 11405), the exposure to each bath was 30 seconds, and the transfer time between the two baths was 5-10 seconds.(19)

De-bonding & Examination of Adhesives Remnants

The samples were tested for shear bond strength using an Instron universal testing machine. A crosshead speed of 0.5mm/minute was used. Readings were recorded in Newtons. The force was divided by the surface area of the bracket base to obtain the stress value in Mega Pascal units.

To estimate the adhesive remnant index, the debonded brackets and the enamel surface of each tooth were inspected under a stereomicroscope (magnification 20X) to determine the predominant site of bond failure. The site of bond failure was scored according to Wang *et al*. classification(20) and as followed:

- Score I: The site of bond failure was between the bracket base and the adhesive.
- Score II: Cohesive failure within the adhesive itself, with some of the adhesive remained on the tooth surface and some remained on the bracket base.
- Score III: The site of bond failure was between the adhesive and the enamel.
- Score IV: Enamel detachment.

Statistical Analysis

Data were collected and analyzed using SPSS software version 15 (2006). In this study the following statistics were used:

a) Descriptive statistics: including means, standard deviations and percentages.
b) Inferential statistics: including independent sample *t*-test: to test any statistically significant difference of the shear bond strengths between groups.

In the statistical evaluation, the following levels of significance are used:

Non-significant	NS	$P > 0.05$
Significant	*	$0.05 \geq P > 0.01$
Highly significant	**	$0.01 \geq P > 0.001$
Very highly significant	***	$P \leq 0.001$

RESULTS & DISCUSSION

A balance in bond strength must be achieved when choosing a bracket-adhesive combination for fixed orthodontic treatment. Bond strength should not only be high enough to resist the forces during the course of orthodontic treatment but also low enough to allow the removal of the bracket without any complications at the end of orthodontic treatment. Therefore, high mean bond strength does not necessarily mean better clinical performance.(7)

The findings of this study can not be thoroughly compared with other studies due to different thermocycling protocol, different adhesives, new light cure unit used with less curing time and sapphire brackets are used for the first time in thermocycling researches.

The results of this study indicated that the SBS of sapphire brackets bonded with light-cured composite and RMGIC is higher than stainless steel brackets in both control and thermocycling groups with a very high significant difference (Table 1). This could be explained by the translucency of sapphire brackets that gives a better chance for a more complete polymerization with light curing in addition to the presence of zirconia particles coating the bracket base that creates millions of undercuts that secure the bracket in place due to the micro-mechanical retention means.

In both types of brackets and adhesives, the SBS in thermocycling group is lower than control group with a non-significant difference except for sapphire brackets bonded with light-cured composite where there is very high significant difference between control and thermocycling groups (Table 1). This may possibly be explained by the absorption of water and the alternating stressing of the system resulting from the large mismatch of the thermal expansion coefficients of the adhesives, brackets and enamel. These differences between the thermal coefficients of the three components of the system are likely to affect adversely the adhesion of the resin to other parts of the system. The cyclical stress may cause any de-bonded regions at the interfaces to grow progressively in size. Because the RMGIC consists of a mixture of two components, namely, glass ionomer and resin adhesive, this extra interface between the two might make this cement more prone to this adverse effect; this comes in agreement with the findings of Arici and Arici.[7]

As shown in table 1, the percentages of reduction of SBS after thermocycling in stainless steel and sapphire brackets bonded with light-cured composite are 3.52% and 60.16 % respectively. On the other hand, the same brackets bonded with light-cured RMGIC showed approximately the same percentages (4.28% and 4.36% respectively).

Comparing the SBS of stainless steel and sapphire brackets, separately, bonded with both types of adhesives reveal that it is higher in composite than RMGIC in control and thermocycling groups with a very high significant difference (Table 2). This indicates that composite is better than RMGIC in this study although some studies agree and others disagree with this result. Increased in the SBS of composite may be attributed to the effect of acid etching of enamel that significantly increased the bond strength of brackets to enamel.

Generally, the mean value of SBS of stainless steel bonded with light-cured composite in this study is nearly similar to that of Garma[21] but for sapphire brackets, it is higher. This may be attributed to the difference in the surface areas of the brackets although the same adhesive, light cure unit and curing time are used.

The site of failure provides useful information about the bonding process. Ideally, in orthodontics, an adequate bond that fails at the enamel-cement interface is desirable because de-bonding and subsequent polishing procedures would become much easier.[22]

Reviewing tables 3 and 4 reveal that in sapphire and stainless steel brackets bonded with RMGIC, the predominant score is III that is most of the adhesive remained on the brackets because RMGIC bonds better to the base of the bracket than to enamel; this comes in agreement with the findings of Toledano *et al*.[22] while disagrees with Arici and Arici.[7]

For sapphire brackets bonded with composite, the predominant scores are scores II and III while for stainless steel brackets the predominant score is score II with 20% score I. With the use of acid-etching technique, almost none of the bonding failures were located at the resin-enamel interface. This may be attributed to the incomplete polymerization of the resin just below the metal base of the bracket. In sapphire brackets score I is absent because of their translucency.

The occurrence of these types of failure sites (scores II and III) may offer a clinical advantage in protecting the adhesive enamel interface from damage. On the other hand, this reduces teeth cleaning time and is less bothersome for the patients.

CONCLUSIONS

1. The shear bond strength of light-cured composite is higher significantly than resin-modified glass ionomer cement.
2. The shear bond strength of sapphire brackets bonded with light-cured composite and RMGIC is higher than stainless steel brackets in both control and thermocycling groups with a very high significant difference.
3. Thermocycling decreases the shear bond strength of the sapphire brackets bonded with composite significantly by 60.16%.
4. The most predominant sites of bond failure are within the adhesive itself and between the adhesive and the enamel.

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(Table 1) Descriptive statistics of shear bond strength and groups differences according to brackets types and thermocycling

Adhesives	Groups	Descriptive statistics				Groups difference	
		Stainless steel brackets		Sapphire brackets			
		Mean	S.D.	Mean	S.D.	t-test	P-value
Composite	Control	9.19	0.62	33.66	1.69	-33.52	0.000 ***
	Thermocycling	8.89	1.28	13.43	1.35	-5.99	0.000 ***
	t-test	0.53		23.04			
	P-value	0.61 (NS)		0.000 ***			
% of reduction after thermocycling		3.52%		60.16%			
RMGIC	Control	3.45	0.25	4.67	0.39	-6.31	0.000 ***
	Thermocycling	3.28	0.16	4.44	0.49	-5.52	0.000 ***
	t-test	1.39		0.87			
	P-value	0.19 (NS)		0.41 (NS)			
% of reduction after thermocycling		4.28%		4.36%			

(Table 2) Descriptive statistics and groups differences according to adhesives types

Groups	Stainless steel brackets						Sapphire brackets					
	Composite		RMGIC		t-test	P-value	Composite		RMGIC		t-test	P-value
	Mean	S.D.	Mean	S.D.			Mean	S.D.	Mean	S.D.		
Control	9.19	0.62	3.45	0.25	21.05	0.000 ***	33.66	1.69	4.67	0.39	41.19	0.000 ***
Thermocycling	8.89	1.28	3.28	0.16	10.61	0.000 ***	13.43	1.35	4.44	0.49	15.37	0.000 ***

(Table 3) Frequency and percentage of occurrence of the adhesive remnant index (ARI) for stainless steel brackets group

Groups	Composite		RMGIC	
Scores	Control	Thermocycling	Control	Thermocycling
I	2(20%)	2 (20%)	0 (0%)	0 (0%)
II	8 (80%)	8 (80%)	0 (0%)	0 (0%)
III	0 (0%)	0 (0%)	10 (100%)	10 (100%)
IV	0 (0%)	0 (0%)	0 (0%)	0 (0%)

(Table 4) Frequency and percentage of occurrence of the adhesive remnant index (ARI) for sapphire brackets group

Groups	Composite		RMGIC	
Scores	Control	Thermocycling	Control	Thermocycling
I	0 (0%)	0 (0%)	0 (0%)	0 (0%)
II	5 (50%)	6 (60%)	0 (0%)	0 (0%)
III	5 (50%)	4 (40%)	10 (100%)	10 (100%)
IV	0 (0%)	0 (0%)	0 (0%)	0 (0%)

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