Shear bond strength of different lingual buttons bonded to wet and dry enamel surfaces with resin modified glass ionomer cement (in vitro comparative study)

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ABSTRACT

Background: This study was aimed to investigate the effect of three lingual button (Nickel free / rectangular base, Nickel free / round base and Composite) and bonding environment, wet and dry enamel surface, on: the shear bond strength (SBS) of light and self-cured Resin Modified Glass Ionomer Cements, and the debonding failure sites.

Materials and method: One hundred twenty no-carious, free of cracks maxillary first premolar teeth were selected. Three types of orthodontic lingual buttons were used in this study: Nickel free / rectangular base, Nickel free / round base and Composite buttons. The teeth were divided into two groups of sixty teeth each. One group was used for testing the chemically cured GC Fuji Ortho Resin modified Glass Ionomer (RMGIC), while the other was used for testing the light cured GC Fuji Ortho LC RMGIC. Each was further subdivided into two subgroup; thirty teeth were bonded to wet enamel surface while the other was bonded after drying the enamel surface. Then each ten teeth from each subgroup were bonded with only one type of buttons. The sample was tested for bond strength using the universal testing machine and the Adhesive Remnant Index (ARI) was inspected under the stereomicroscope.

Results:The highest (SBS) values were obtained in the Nickel free / round base button with both types of RMGIC in wet and dry environment as revealed by ANOVA test. While t-test revealed that both systems of RMGIC yield relatively lower values of (SBS).

Conclusions:The GC Fuji Ortho RMGICs resist shear force in dry better that in wet environment.Nickel free / round base buttons give the greatest shear bond strength among the three types of button.The composite buttons give greater bond strength in dry than in wet environment with both GC Fuji Ortho and GC Fuji Ortho LC RMGICs.

Key words: Shear bond strength, lingual buttons, RMGIC. (J Bagh Coll Dentistry 2013; 25(1):146-152).

INTRODUCTION

Since bonding procedures have been improved, direct bonding of molar tubes and lingual buttons is frequently practiced in current orthodontics, the bond strength of orthodontic brackets has been widely tested; however, there are no sufficient studies investigating the bond strength of different lingual buttons types and which one is clinically more preferable than the other [(1)].

Although in vitro lingual bond strengths are comparable with labial bond strengths [(2)], the bond strength of lingual buttons on lingual surface might be relevant because the oral condition is different in this area, due to the higher risk of contamination with saliva [(1)].

Resin Modified Glass Ionomer Cements were introduced that combine the properties of composites and glass ionomersand overcomethe glass ionomer disadvantage of relatively low shear bond strength[(3)].

Although traditional bond materials must be applied in completely dry and isolated fields to produce clinically acceptable bond strengths [(4)].

Some manufacturers have started to introduce hydrophilic substances into their compositions. These substances allow for greater shear bond strength on wet surfaces [(5)].

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These hydrophilic bond systems have been considered as an important development in orthodontic practice because many routine clinical procedures are not carried out under ideal conditions [(6)].

Since there is no previous Iraqi study measuring the shear bond strength at the lingual surface, this study was carried out to investigate the shear bond strength of three lingual button types (Nickel free / rectangular base, Nickel free / round base and Composite) bonded to wet and dry enamel surface with chemical cured and light cured RMGIC, and to measure their ARI.

MATERIALS AND METHODS

The Sample

Three hundred eighty seven extracted human maxillary first premolar teeth were collected, which have been extracted from patients seeking orthodontic treatment; The collected teeth were stored in normal saline (Sodium Chloride solution 0.9%) containing crystals of Camphor phenol (Thymol) to prevent dehydration and bacterial growth in closed container at room temperature until preparation and testing[(7)]. After examining the teeth with 10X magnifying lens [(8)] one hundred twenty teeth were selected, they were having grossly intact lingual enamel surface with no surface cracks, free of caries [(9)]and not subjected to any pretreatment chemical agents, such as hydrogen peroxide or formalin. Three types of lingual buttons were used in this study: Nickel free / rectangular base buttons, Nickel free / round base buttons and Composite (OrthoFlex®) buttons. The base surface area of the buttons were 9.6224mm², 9.625 mm² and 5.8425 mm² respectively, as provided by the company (Ortho Technology company, USA).

Method

The selected one hundred and twenty teeth were divided into two equal groups (1 and 2), containing sixty teeth each according to the type of orthodontic adhesivegroup 1 was bonded with chemical cure RMGIC (GC Fuji Ortho, GC Corporation/Japan), while group 2 was bonded with light cured RMGIC (GC Fuji Ortho LC, GC Corporation/Japan).

Group 1: The light cured samples were subdivided into two subgroup according to the condition of enamel surface (wet or dry) containing thirty teeth each:

Subgroup A was bonded to wet enamel surface

Subgroup B was bonded after drying the enamel surface

Group 2: The chemically cured samples were subdivided into two subgroup according to the condition of enamel surface (wet or dry) containing thirty teeth each:

Subgroup C was bonded to wet enamel surface

Subgroup D was bonded after drying the enamel surface

Then within each subgroup (A, B, C, and D):

1st ten teeth were bonded with Nickel-free rectangular base buttons,

2nd ten teeth were bonded with Nickel-free round base buttons, 3rd ten teeth were bonded with Composite buttons**.**

Retentive grooves were made on the roots of the teeth to increase the retention of the teeth inside the acrylic blocks**[10]**. Each tooth was fitted on the glass slide using a sticky wax and was positioned so that the middle third of the lingual surface is oriented to be parallel with the analyzing rod of dental surveyor[11, 12](Fig. 1). Another three teeth was placed in the same manner with a distance of 1 cm between each other. Then two L-shaped metal plates, were painted with a thin layer of separating medium (Vaseline) **[11]** which then were placed around the teeth (Figure 1). Then the powder and liquid of the self-cured acrylic were mixed and poured around the teeth to the level of the cementoenamel junction**[13].** After setting of the self-cured acrylic resin, the two L-shaped metal plates were removed and the specimens were coded and stored in normal saline solution containing crystals of thymol until bonding**[14]**.

The lingual surface of each tooth of the twelve subgroups was polished using non-fluoridated pumice/water mixture with a rubber cup attached to a low speed handpiece for 10 seconds **[15].**Then each tooth was washed with water spray for 10 seconds **[13, 16]** then dried by oil-free air for 20 seconds**.**

Subgroup A: The bonding was done according to manufacturer instruction. After polishing, the enamel surface of each tooth in this subgroup was prepared wet using a cotton roll soaked in distilled water before the button was bonded **[17].** The standard powder to liquid ratio was 3.0g/1.0g was mixed. Immediately after applying the adhesive to the button base, the button was placed gently onto the middle third of the lingual surface using a clamping tweezers.A constant load was placed on the button for 10 seconds **[18]**to ensure seating under an equal force and to ensure a uniform thickness ofthe adhesive and prevent air entrapment which may affect bond strength [19] (Fig. 1). Each button was then light cured for 40 seconds (10 seconds on each mesial, distal, occlusal and gingival side) (According to manufacture instruction) at a distance of 1 mm from the button **[18]**using the “LED” light cure unit (Woodpecher Co., China). The adjacent teeth were covered with polishing rings before curing (to protect them from the effect of light cure unit) **[20]**. After the completion of the bonding procedure, the teeth were immersed in normal saline **[13]** and stored in the incubator at 37°C for 24 hours after which they were shear tested to debond**[10, 17, 18].**

Subgroup B: Bonding procedure was done in the same stepsof the subgroup A except that after polishing, the enamel surface was dried before bonding with oil-free air for 20 seconds **[21].**

Subgroup C: Bonding procedure was done in the same steps of the subgroup A except that the bonded buttons were left on bench to allow the adhesive to self-cure approximately 7 minute from the start of mixing time without exposure to light.

Subgroup D: Bonding procedure was done in the same steps of the subgroup B except that the bonded buttons were left on bench to allow the adhesive to self-cure approximately 7 minutes without exposure to light.

The shear test was carried out using a Tinius-Olsen Universal testing machine with a crosshead speed of 0.5 mm/minute **[1, 22, 23]**(Fig. 2), the reading were recorded in Newtons. The force was divided by the surface area of the button base to obtain the stress value in Mega Pascal units.

After debonding, the enamel surface of each tooth was examined under X10 magnification with the stereomicroscope to determine the amount of residual adhesive remaining on each tooth [1, 24]. The adhesive remnant index (ARI) scores were recorded as described by Wang *et al.* [25]as follows**:**

Score I: 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: adhesive failurebetween the adhesive and the enamel.

Score IV: Enamel detachment**.**

Statistical analysis

Data were collected and analyzed using SPSS (Statistical Package of Social Science) software version 17 for windows XP. In this study the following statistics were used:

A. Descriptive statistics: Including mean, standard deviation, minimum, maximum, and percentage.

*B. Inferential statistics:*including:

1. One way analysis of variance (ANOVA): To test any statistically significant difference among the shear bond strength of different bonding agents and the difference among different button material through using F (Fissure exact) test.

2. Least significant difference (LSD): When ANOVA showed a statisticalsignificant difference. The LSD will be used to test any statistically significant differences between each two subgroups within the same group.

*3. T-test:*To test any significant differences between mean shear bond strength of each two subgroups at different enamel surface condition (wet and dry enamel surface).

*4. Chi-square***:** To test any statistically significant differences between the groups for the failure site examination results.

P (Probability value) level of more than 0.05 was regarded as statistically non-significant. While a P-level of 0.05 or less was accepted as significant as follows:

$0.05 \geq P > 0.01$ * Significant.

$0.01 \geq P > 0.001$ ** Highly significant.

$P \leq 0.001$ *** Very Highly significant.

RESULTS

Generally, SBS values were compared between the three lingual buttons types in wet and dry environment by using the light and self-cured RMGIC adhesive systems.

Effect of different button types

The highest SBS values were found in Nickel free / round base buttons in both environments with non-significant difference between wet and dry enamel surface, while the Nickel free / rectangular base yielded lower values of SBS than the previous type inboth environments with also, a non-significant difference between wet and dry enamel surface. The Composite buttons showed a highly significant difference between the two environments with higher values in dry environment (Table 1).

Effect of different environments

The light cured (GC Fuji Ortho LC) RMGIC adhesive showed non-significant difference between wet and dry environments, while the self-cured (GC Fuji Ortho) RMGICadhesive yields higher values of SBS in dry environment with a significant difference between the two environments (Table 2).

Effect of different adhesive systems

There was non-significant difference between the SBS values of the light cured (GC Fuji Ortho LC) and the self-cured (GC Fuji Ortho) RMGIC adhesives with relatively lower values of SBS obtained from both adhesives (Table 3).

Adhesive Remnant Index "ARI"

The attachment base-adhesive failure (score I) was most predominant (50 %) in wet environment in the samples bonded with Light-Cured RMGIC using Nickel free / rectangular base buttons.While the cohesive failure (score II) was most predominant (60 %) in dry environment in the sample bonded with Self-Cured RMGIC using Nickel free buttons, andin wet environment in the samples bonded with Self-Cured RMGIC using composite buttons. While the adhesive-enamel interface failure (score III) was most predominant (80 %) in wet environment in the samples bonded with Light-Cured RMGIC using Composite buttons. However, the scores never reached (score IV) in any specimen (Table 4).

DISCUSSION

Nickel-free / round base metal buttons (Fig. 3) showed the highest value of SBS than the two other types of button. This result could be due to the surface area of the button base (9.625 mm^2) which is closed to the adequate surface area for retention 6.8 mm^2 as proposed by Mac Coll *et al.* [26] and this in agreement with Wang *et al.* [27], while disagree with Sőderholm *et al.* [28]who reported that the enlarging the surface area will increase the load carrying capacity and there is an inverse relationship between bond strength and bonded surface area.

Nickel free/rectangular base metal button showed lower mean values of SBS. This result could be due to the poor adaptation between the button base and the tooth surface, the wider area of the rectangular base mesiodistally sometimes may not fit or resemble the curvature of the lingual surface of the tooth, resulting in thick adhesive layer that could result in weak bond strength, and this comes in accordance with Arici*et al.*[29] who concluded that too much increase in the RMGIC thickness will result in lower values of bond strength that encountered to the polymerization reactions.

The composite buttons showed lowest mean values of SBS in wet environment, this result could be attributed to the button base design which only provided with three relatively large dove tail grooves (Fig. 3), this is in agreement with Garma *et al*. [10] and disagreement with Soderquist *et al*. [30] who reported that bond strength of attachmentswith integral bases were shown to be improved whenresin cement was used. In addition, the result could be due to the smaller surface area of the button base as compared to those of Nickel free / metal type, and this agrees with Wang *et al*. [27], and disagree with Kwong *et al*. [31] who shown an inverse relationship between bond strength and bonded surface area.

The Self-Cured adhesive yielded a higher value of SBS in dry environment, this might be explained that in the Self-Cured system with the absence of wet enamel surface, the initiation of water-soluble HEMA monomer will take place upon mixing by the chemically activated free-radical polymerization approach and the final hardening and strengthen of the adhesive is enhanced by the formation of polycarboxylate salt matrix [32]. While the Light-Cured adhesive showed no significant difference between wet and dry environment, this could be due to the addition of hydrophilic HEMA monomer [32, 33], which enables the adhesive to pass beyond resin coating formed by moisture on enamel surface [5]. This results is in disagree with Coups-Smith *et al*. [17] and Al-Shamsi *et al*. [34] who demonstrated that Fuji Ortho LC performs significantly better shear bond strength on wet enamel.

At both environment / attachment combinations there was no significant difference between the Self-Cured and Light-Cured RMGIC adhesives, this might be due to same compositions of both system [32]. This result in disagree with Coups-Smith *et al*. [17] who stated that the Self-Cured cement provided significantly higher bond strength than the Light-Cured system.

These results were lower than the accepted clinical minimal value of shear bond strength (5.9 MPa) as proposed by Renyolds and Von Fraunhofer[35], which might be accounted to that enamel surface of all teeth was not conditioned which might lead to weak mechanical retention. This result is in accordance with (Godoy-Bezerra *et al*. [36] while disagree with Ewoldsen[37]who found no significant differences between none conditioned and conditioned enamel.Also, the results could be explained by that the enamel surface was not etched. The bond strength of RMGICs has been shown to be reduced by one-third to one-half without acid etching because 37% phosphoric acid produces a qualitatively rougher enamel surface, thus facilitating the penetration of the adhesive resin[38].

<u>Score I</u> was most predominant (50%) in wet environment in the samples bonded with Light-Cured RMGIC using Nickel free / rectangular base buttons. This is, probably, because of the air entrapment behind the base of the button which significantly affects polymerization and may produce lower bond strength between the button and the adhesive material [39], this is in agree with Toledano *et al*. [40].

<u>Score II</u> was most predominant (60 %) in dry environment in the samples bonded with Self-Cured RMGIC using Nickel free buttons, also it was predominant in wet environment in the samples bonded with Self-Cured RMGIC using composite buttons,it could be due to the small projections of metal buttons which acted as a stress concentration areas from which the adhesive failure may begin and propagate through the remaining part of the adhesive, this is in agree with the finding of Maijer and Smith [39].

In orthodontic bond strength testing, cohesive fractures reflect the internal strength of the adhesive rather than the actual adhesion to the surface under study [41].

<u>Score III</u> was most predominant (80 %) in the sample bonded with Light-Cured RMGIC using Composite buttons in wet environment.When using RMGICs, and especially when acid etching is not used, almost all the failure sites were at the cement-enamel interface [40]. This finding could be due to the reduced depth of demineralization.

<u>Score IV</u> was absent, which means that even the highest bond strength values were not sufficient to damage the enamel surface. This result comes in accordance with Santos *et al.*[5].

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Table 1: Descriptive statistic of SBS in different environments using three types of buttons.

Buttons	Environment	Descriptive Statistics		Differences in environment	
		Mean (MPa)	S.D.	t-test	P-value
Nickel-free / rectangular base (I)	Wet	3.73	1.02	-0.35	0.73 (NS)
	Dry	3.91	1.07		
Nickel-free / round base (II)	Wet	6.21	1.28	0.64	0.52 (NS)
	Dry	5.82	1.51		
Composite (III)	Wet	3.04	0.37	-2.97	0.005 **
	Dry	4.75	1.18		

Table 2: Descriptive statistics of SBS of RMGIC adhesives in different environments.

Adhesive	Environments	Descriptive statistics		Differences in environments	
		Mean (MPa)	S.D.	t-test	P-value
Self-cured	Wet	3.89	1.02	-2.5	0.015 *
	Dry	5.25	1.16		
Light-cured	Wet	4.76	1.2	0.71	0.48 (NS)
	Dry	4.39	1.06		

Table 3: Descriptive statistics of SBS of RMGIC adhesive systems.

Adhesive	Descriptive statistics		Differences in Adhesive	
	Mean (MPa)	S.D.	t-test	P-value
Self-cured	4.575	1.12	-0.013	0.99 (NS)
Light-cured	4.580	1.09		

Table 4: Distribution and percentage of adhesive remnant index.

Adhesive	ARI	Wet						Dry					
		Nickel free/ rectangular base button		Nickel free/ round base button		Composite button		Nickel free/ rectangular base button		Nickel free/ round base button		Composite button	
		No	%	No	%	No	%	No	%	No	%	No	%
Self-cured	I	1	10	1	10	1	10	0	0	1	10	1	10
	II	3	30	2	20	6	60	6	60	6	60	2	20
	III	6	60	7	70	3	30	4	40	3	30	7	70
	IV	0	0	0	0	0	0	0	0	0	0	0	0
Light-cured	I	5	50	4	40	2	20	4	40	4	40	1	10
	II	2	20	3	30	0	0	2	20	3	30	2	20
	III	3	30	3	30	8	80	4	40	3	30	7	70
	IV	0	0	0	0	0	0	0	0	0	0	0	0

Figure 1: ***A*, Fitting the tooth with a sticky wax and oriented so that the middle third of lingual surface is made parallel to the analyzing rod of surveyor. *B*, two L-shaped metal plates placed around the teeth. *C*, load placement over each button.**

Figure 2: Shear bond strength test

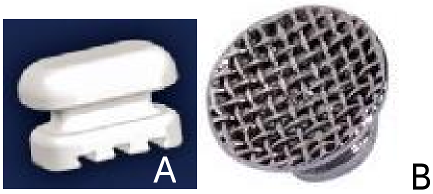

Figure 3: Composite button (A), Nickel free/round base button (B) used in this study.