The effect of light intensity and curing time of light emitting diode on shear bond strength using different types of bracket's materials

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ABSTRACT

Background: This study was intended to evaluate the effect of two LED devices which has different light intensity and curing time on the shear bond strength (SBS) using stainless steel and two other esthetic brackets.

Materials and method: Sixty first premolar teeth were selected. Three types of orthodontic brackets were used in this study: stainless-steel brackets, the other two types are esthetic ceramic brackets. Two high intensity LED units were used, the first one was of a lower intensity (HANGZHOU SIFANG, China), the output power 1200 mW/cm^2, the second source had the higher intensity (FlashMax P3, Denmark) which has power intensity of 4000 mW/cm^2. The teeth were divided into two groups (Aand B) of 30 teeth each. Group A was used for testing HANGZHOU SIFANG device in standard cure time (20s) , while the group B was used for testing Flash Max P3 device in fast curing mode(6s). A and B groups were further subdivided according to bracket type into three subgroups of 10 teeth each. SBS of all subgroups were tested by using an Instron universal testing machine, ARI was assessed at (20X) magnification.

Results: The clinically acceptable SBS were excelled in both the standard and fast curing mode groups for all bracket types, significant differences were found only when comparing the Pure with the other two types of brackets in the same group. Comparing each bracket type between group A and group B reveals a significant difference only at stainless-steel type brackets.

Conclusions: the new high intensity curing devise gave comparable SBS to the LED units previously available with shorter time.

Key words: high intensity LED, esthetic brackets. (J Bagh Coll Dentistry 2012; 24(4):132-138).

INTRODUCTION

The use of light-cured composite material for bonding orthodontic brackets has become increasingly popular among orthodontists because of their ease of use and extended time for precise bracket positioning, however this extended curing time considered inconvenient for both orthodontist and patient, therefore; various methods were suggested to reduce chair-side time including the use of self-etching primers[1], precoated brackets[2], and the use of curing lights with higher intensity to enhance the polymerization of adhesives[3]

A variety of curing lights are available to photopolymerize light-cured dental resins and adhesives. The most common visible light-curing unit still used by orthodontists is the quartz – tungsten – halogen (QTH) unit[4]. Several surveys have reported that QTH curing units deliver an inadequate light intensity[5]. A 40-second light curing time per site is recommended to gain an adequate polymerization. The total light curing time thus approaches 15 minutes, which is too long for both the orthodontists and the patients[6].

plasma arc curing unit (PAC) produces high intensity lights delivering more than 1800 mW/cm^2, which is nearly fourfold greater compared with the conventional QTH[7], several studies stated that six to nine seconds produced an adequate physical property of resins and resin-reinforced glass ionomer cements equal to those produced with 40-second exposures of conventional QTH[8-10]. However, PAC units have several disadvantages, e.g., they are expensive and of a relatively large size and complex construction[11].

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The light-emitting diode (LED) is a new technology for light polymerization in orthodontics; LED curing devices are considered as a serious competitor for the QTH lights[12,13].

several advantages are recorded for LED curing devices, instead of the hot filaments used in halogen bulbs, LEDs are a general source of continuous light with high luminescence efficiency, based on the general properties of a simple twin-element semi-conductor diode encased in a clear epoxy dome that acts as a lens with lamp duration time of approximately 10 000 hours[14], no heat generation, and resistance to shock and vibrations[14,15]. The appliance consumes little power and can be run on rechargeable batteries, As a result, manufacturers introduced various cordless, lightweight units used in both operative dentistry and orthodontics with simple economic designs [16]. Consequently, LED technology has a promising future.

Irrespective of the light unit used, it should be capable of adequately polymerizing the material, the polymerization capacity of which is directly related to the light power as well as irradiation time. If the resin material is adequately polymerized, a higher bond strength is expected in comparison with a material with a lower degree of conversion[17].

The new generation of LED curing units with a high light intensity above 1,000 mW/cm^2 has been found to cure composites in half the time of QTH devices[16,18-20] and become comparable to PAC units from time point of view[17]. Both high intensity LED and esthetic bracket have especial concern in the modern orthodontics, as both innovations aim to satisfy patient demands regarding compliance and esthetics respectively.

This study aims to merge these two innovations by examining the effect of two commercially available powerful LED devices which has different light intensity and curing time on the shear bond strength using stainless steel and two esthetic ceramic brackets .

MATERIALS AND METHODS

Teeth

Sixty human maxillary premolar teeth were included in this study. After extraction the teeth were washed under tap water and cleaned to remove blood, soft tissue and debris, then they were stored in distilled water containing crystal of thymol in closed container at room temperature until preparation and testing, The water was changed periodically to avoid bacterial growth.

To meet the criteria for selection in this study, the teeth were selected, only if they had intact buccal enamel, had not been pretreated with chemical agents (eg, H2O2), had no surface cracks due to the pressure from the extraction forceps, and were caries free, they were cleaned and polished with nonfluoridated flour of pumice and rubber prophylactic cups for 10 seconds[21,22].

Brackets

In this study three types of orthodontic brackets were used: the first one is the conventional metallic brackets: stainless-steel (Bionic®) brackets, the other two types are esthetic ceramic brackets: polycrystalline aluminas ceramic (Reflections®) brackets, and monocrystalline aluminas sapphire (Pure®) brackets, The base surface area of the Bionic®, Reflections®, and Pure® brackets were: 10.9 mm^2, 12.2 mm^2, and 11.9 mm^2 respectively, as provided by the manufacturer company (Ortho Technology Company, USA). Bionic is equipped with 80 gauge foil mesh bonding base, Reflection bracket has three dove tail grooves. The Pure bonding base is coated with zirconia powder creating millions of undercuts that mechanically lock with the bracket adhesive. All bracket types used were of standard edgewise system.

Curing Light

Two LED curing light units with different intensities were used, both of high light intensity type. The first curing light was of lower intensity (HANGZHOU SIFANG MEDICAL APPARATUS Co., China),the output power 1200 mW/cm^2, the average depth of resin solidification is 2mm after 20 second light radiate (normal mode curing) see Fig.1-A).

The second source of curing light had higher intensity (FlashMax P3 by: CMS ApS Dental Co., Denmark) has power intensity of 4000 mW/cm^2 with curing depth average about 4mm after 3second light radiate (fast mode curing) see Fig.1-B).

Figure 1: *A*, Hangzhou Sifang medical apparatus curing device with output power 1200 mW/cm^2*B*,. FlashMax P3, power intensity of 4000 mW/cm^2.

Teeth mounting

All the teeth were mounted in acrylic blocks, first of all cavitations were made along the side of the root at two different levels by diamond wheel bur, later on these cavitations would be filled with the acrylic to prohibit any movement of the teeth during shear test. Small amount of soft sticky wax was used to fix each tooth on a glass slab. The analyzing rod of the surveyor was used to align the facial surfaces of the teeth perpendicular with the surface of the glass slab (Fig.2, A). This alignment allow the buccal surface of the tooth parallel to the applied force during the shear test[21], three teeth were aligned on the same glass slab separated by equal distance (Fig.2, B). Then two L-shaped metal plates, were painted with a thin layer of separating medium and placed opposite to each other to form a box around the teeth (Fig.2, C)

Powder and liquid of self cured acrylic were mixed and poured around the teeth to the level of the cement-enamel junction of each tooth. After acrylic setting, the two metal plates were removed. Each specimen was divided into four blocks holding only one tooth using electrical saw, so that every tooth can be bonded and tested separately. The size of each block should be suitable for fitting in the jaw of Instron machine. The mounted teeth were stored in distill water containing thymol crystal to prevent dehydration and bacterial growth until bonding procedure.

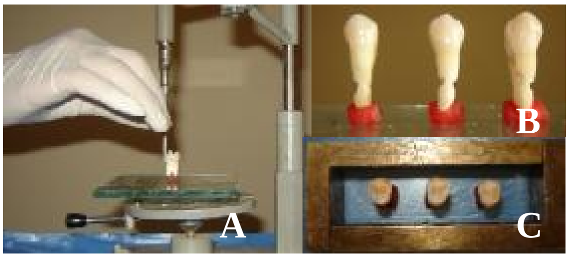

Figure 2: *A*, fitting of the tooth on a glass slab with a soft sticky wax, analyzing rod of the surveyor was used to align the middle third of the buccal surface. *B*, three teeth were aligned on the glass slab, retentive wedge shaped cuts were made along the sides of the roots of each tooth. *C*, the two L-shaped metal plates placed opposite to each other to form a box around the teeth.

Sample organization

The selected sixty teeth were divided into two main groups, A and B groups. Both of them were bonded using light-cured resin (Resilience®, OrthoTechnology Company, USA). Group A was used for testing the lower intensity curing light with normal curing time, while group B was used for testing the higher intensity curing light with short curing time. Both groups were divided into three subgroups of 10 teeth each 1:

Group A1, B1 had stainless steel (Bionic®) brackets.

Group A2, B2 had Polycrystalline ceramic (Reflections®) brackets.

Group A3, B3 had monocrystalline ceramic , sapphire (Pure®) brackets.

Bonding

The established procedure for bonding brackets to enamel with composite resin requires a series of preparatory steps. All the teeth were first polished with nonfluoridated pumice using a rubber prophylactic cup and then rinsed with a stream of water[23], and then dried with non oil air, each one of the three previous steps were performed for complete 10 seconds. 37% phosphoric acid gel was applied for 15 seconds; the teeth were rinsed under running water for 20 seconds, and dried with oil- and moisture-free compressed air for 20 seconds. Immediately following the drying, the samples were inspected for the characteristic dull, white, frosted appearance of adequately etched enamel before applying and air thinning the manufacturer supplied primer.

The bracket with the adhesive material light-cured resin (Resilience, Ortho Technology Company, USA) was placed on the tooth, pressed firmly onto the enamel on the middle of the buccal surface, any excess material was removed with sharp explorer without disturbing the bracket[7], 300 gm load fixed to the vertical arm of the surveyor was applied for 10 seconds on the bracket surface, to standardize the pressure applied on the brackets during bonding [24].

For group A (standard curing mode), the LED source was from HANGZHOU SIFANG MEDICAL APPARATUS Co., China that was applied mesially and distally for 40 seconds (20 seconds for each side).

For group B (fast curing mode), the LED unit was Flash Max P3 by: CMS ApS Dental Co., Denmark, that was applied mesially and distally for 6 seconds (3 seconds for each side). The distance between the light guide tip of both LED types and the bracket base was of minimum separation (1-2) mm. The above chosen curing times express the recommendation given by the respective light curing device manufacturer, see Fig.3A, B, C.

Fig.3: A, normal mode curing with Hangzhou Sifang medical apparatus curing device. B, fast mode curing with FlashMax P3.C, single specimen of group A1 after bonding.

Shear bond test;

All the bonded teeth were placed in normal saline for 24 hours until bracket debonding. Instron universal testing machine were used to test the shear bond strength (SBS) with crosshead speed of 0.5mm/minute, readings were obtained from the machine in Newtons. Then force was divided by the surface area of the bracket base to obtain the stress value in Mega Pascal Units.

Adhesive remnant index (ARI)

After debonding procedure, magnifying lens (20X) of a stereomicroscope was used to examine the enamel surface and bracket base of each tooth. ARI scores were assessed. The enamel surface was scored according to Wang[25]classification as follows: *Score I:* Failure between bracket base and adhesive. *Score II:* Cohesive failure within the adhesive itself. *Score III:* Adhesive failure between adhesive and enamel. *Score IV:* Enamel detachment.

RESULTS

Descriptive statistics illustrated in Table1 reveled different mean values of shear bond strength (SBS) of the six subgroups with the highest mean value found at group B3 Pure fast curing mode, while the lowest was seen in group B1 Bionic fast curing mode.

The results of the one-way ANOVA comparing the SBS between the different bracket types revealed significant differences in standard curing mode group A, and in fast curing mode group B there was a very highly significant difference. LSD test was performed to show the exact positions of these differences; it's showed that for both groups A and B, significant differences were found only when comparing the Pure with the other two types of brackets (Table1).

T-test was also performed to show if there is any statistical significance comparing each bracket type between group A and B, it showed a significant difference only at Bionic type brackets (Table1).

Regarding the ARI scores, the results were shown in Table 2.

DISCUSSION

Despite innovations in curing light devices with short exposure time it has to be proven if this time saving improvements have an effect on bond strength which is highly important for treatment outcome. High bond strengths are required in order to avoid bracket failure during treatment while on the other hand brackets should be removable without any enamel damage[26].

The mean values of shear bond strength of each one of the six subgroups in this study can be discussed under the illumination of different affecting factors, total energy absorbed by the adhesive, the material of the bracket and its effect on the light transmittance and the retention mean of each bracket type.

In the standard cure group A, where the curing time is constant for each subgroup the highest SBS mean values were found in group A3(pure brackets), and that logical as the degree of cure of the adhesive is influenced by the translucency of the bracket and this would increase SBS, previous studies showed that monocrystalline alumina brackets had the highest diffuse transmittance values, followed by polycrystalline alumina [27,28] and in respect to the retention mean factor the Pure base is coated with zirconia powder creating millions of undercuts that mechanically lock with the bracket adhesive and provide excellent retention that would rather increase SBS for the same curing time.

The lowest shear bond strength expressed in the subgroup A2 may be explained under the effect of retention mean of only three dove tail grooves that mechanically retain the bracket, indeed this lowest values considered as privilege as the rigid, brittle nature of both the ceramic bracket and the underlying enamel results in a poor environment for absorption of stress during debonding[29]. If the bond between the adhesive and the enamel is stronger than the enamel itself, the enamel will fracture during debonding. Furthermore, since these brackets are very brittle and elongate less than 1 per cent before fracturing, bracket fractures can often occur during debonding, with large amounts of the bracket material remaining on the tooth, removal of which requires the use of abrasive burs that may also cause enamel surface loss. These problems have led most manufacturers to produce ceramic brackets with decreased bond strengths between the base and the composite resin[30]. A1 sub group had intermediate SBS between the three sub groups as the SBS increased by 80 gauge foil mesh at the bonding base of the bracket, it also decreased by the opaque stainless material the bracket made of. Although these differences in the SBS between the sub groups, LSD test showed no statistical difference between group A2, A3, and statistical differences was only present between group A3 and the other two groups.

In the fast cure group B, the curing time is constant for the three subgroups B1, B2 and B3 the result reveled the highest SBS mean values lies in the same bracket type (for the same above discussed reasons), the lowest SBS values was seen in the subgroup B1 (Bionic brackets), while the in-between SBS mean values was found in group B2 (Reflection brackets). For group B1(Bionic) it might be reasonable to point out that the 6 seconds of curing time was not enough to increase the shear bond strength to comparable values of group A1(Bionic) and overcome the opaque nature of stainless steel therefore some literature recommended longer curing time for metal bracket than ceramic brackets[31], LSD test again revealed statistical differences was only found between group B3(Pure) and the other two sub groups reflecting the statically significant increase of SBS of Pure brackets over the other two brackets type.

Regarding the effect of curing time and light intensity on each bracket type in the standard A and fast B curing groups. The curing of the composite is affected by the total light energy reaching it. Total light energy is the combined effect of the intensity of the curing light (density of the light in mW/cm^2), the duration of the light exposure, and the distance between the light guide tip and the composite (light energy decreases by the square of the distance). Studies have demonstrated that the greater the total light energy applied to the composite, the greater the polymerization, the greater the flexural strength, and the greater the bracket bond strength[32-34] .

Descriptive statistics showed that esthetic brackets in group (Pure and Reflection) had higher SBS mean values in the higher light intensity group , yet T- test revealed that they are Statistically, considered equivalent. Since the distance between brackets and the light source is constant in the present study. Therefore, it is logical to assume that increasing the curing light intensity would decrease the time needed to polymerize the adhesives for the same adhesives bond strength. These results agreed with many researches considering the light source power is the manipulating factor, Rueggeberg[35], Rahiotis[36] *et al* and Peutzfeldt and Asmussen[37] who observed that the greater the total energy during polymerization ,the higher the SBS values. However, Niepraschk *et al.*[38] and Dall'Igna *et al* [17], stated that the degree of polymerization of the resin had a greater relationship with the time of exposure to light than to its power, in contrary to the results of the present study. Statistically significant difference was only seen at Bionic bracket type between the two curing mode and it might be explained for the bracket material opacity effect on shear bond discussed above.

Regarding the ARI scores, no definite pattern can be strictly recognized, rather than that it's reasonable to figure out a relationship between lesser SBS mean values and score I % failure between bracket base and adhesive, while cohesive (score II) and adhesive (Score III) failure could be seen more with increasing SBS mean values.

The required clinically acceptable bond strength of 6–8 MPa suggested by Reynolds[39]and described in the majority of the available studies were even excelled when looking at the means of SBS were got from the standard and fast curing mode groups for all bracket types, making the use of the new high intensity curing device 4000 mW/cm^2 comparable to the LED units previously available , indeed further researches suggested to lower the curing time than 6 seconds with the same high intensity device depending on the total energy basis.

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Table.1: Descriptive statistics, ANOVA and T-test for Shear Bond Strength for the tested six groups

Shear Bond Strength	**Bracket Type**	**Group A 40Sec**				**Group B 6Sec**			
		Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
	SS(Bionic®)	9.45	18.35	12.86	2.63	2.66	16.33	7.04	4.21
	Ceramic(Reflections®)	9.10	13.69	10.81	1.40	9.02	11.48	9.79	0.84
	Sapphire(Pure®)	9.66	20.50	15.96	4.97	11.68	21.43	16.05	3.91
ANOVA		**df**	**MS**	**F**	**Sig**	**df**	**MS**	**F**	**Sig**
		29	67.11	5.991	0.01	29	213.4	18.97	0.00
LSD		within group A				within group B			
		1	2	0.182		1	2	0.078	
		1	3	0.048		1	3	0.000	
		2	3	0.002		2	3	0.000	
		t	**df**	**Sig.**					
Independent Samples t-Test	**SS(Bionic®)**	3.71	18	0.002					
	Ceramic(Reflections®)	1.98	18	0.063					
	Sapphire(Pure®)	0.05	18	0.963					

Table 2: Scores of Adhesive Remnant Index for each of the six groups

Group	scoreI(%)	scoreII(%)	scoreIII(%)	scoreIV(%)
A1	0(0)	8(80)	2(20)	0(0)
A2	7(70)	3(30)	0(0)	0(0)
A3	0(0)	4(40)	5(50)	1(10)
B1	6(60)	2(20)	2(20)	0(0)
B2	0(0)	9(90)	1(10)	0(0)
B3	0(0)	7(70)	3(30)	0(0)