

Effect of Reducing Curing Time on the Shear Bond Strength of Metal Orthodontic Brackets: An *In Vitro* Comparative Study

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Abstract: *Background:* The aim of this study was to evaluate the effect of different curing time of LED light cure on the shear bond strength of stainless steel orthodontic brackets bonded to human teeth in comparison with light exposure of 40 seconds from a conventional halogen-based light-curing unit which was used as a control. *Materials and Methods:* Thirty sound maxillary premolar teeth extracted from patients seeking orthodontic treatment were selected for this study. These teeth were divided into three equal groups. In the first group, the brackets were bonded using Halogen light cure for 40 seconds. In the second group, the brackets were bonded using Woodpecker i-Led light cure for 3 seconds, while in the third group, the brackets were bonded using Woodpecker i-Led light cure for one second. The samples were evaluated for bond strength using an Instron universal testing machine 24 hours after bonding procedure, while for adhesive remnant index, the enamel surface and bracket base of each tooth were examined under magnifying lens (20X) of a stereomicroscope. One way ANOVA and Tukey's tests were used to compare the shear bond strength among the groups, while Pearson's chi-square was used to assess the adhesive remnant index. *Results:* The shear bond strengths of both groups of LED unit were higher than halogen one, with a statistically high significant difference. Score 2 and 3 were the predominant scores for the adhesive remnant index, with a non-significant difference among tested groups. *Conclusions:* Both of the LED unit's groups showed clinically acceptable shear bond strength in comparison to halogen, so the time of bonding reduced without jeopardizing the shear bond strength or enamel surface after debonding.

Keywords: Shear bond strength, Light cure, Curing time

1. Introduction

Buonocore simplified the bonding of orthodontic brackets after his introduction of acid etch bonding technique in 1955 [1] and eliminated the need of orthodontic bands unless in few cases. Nowadays, two types of composites are used in bonding brackets namely no-mix and light cure adhesives.

Tavas and Watts [2] were the first who reported bonding of orthodontic brackets using visible light cure composite. Light cure adhesives had many advantages like adequate working time to position the brackets properly, ease in excess adhesive removal, the risk of contamination with saliva or blood was reduced, and ... etc [3]. The main disadvantage of light cure composite is the time spent to cure the composite to get passable polymerization of the composite to resist the force applied during ligation of the first arch wire [4,5].

There are three sources for delivering visible blue light to cure the composite; quartz-tungsten-halogen (QTH) visible light, Plasma arc (xenon light) and light-emitting diode (LED) [6,7].

Halogen type contains bulbs producing light when the electrical energy heats the tungsten filaments [8]. The main disadvantages of this type are the long time for curing the composite that is uncomfortable to the patients, not practical with children, awkward for the orthodontists [9,10] and the bulbs of the light had short effective time, thus needing replacement every six months [11]. This results in decreasing the curing effectiveness and risk of bond failure [12]. This type endows with a light intensity

of about 500 mW/cm² and a wavelength range of 420 to 500 nm.

Plasma arc lamps had a tungsten anode and a cathode in a quartz tube filled with xenon gas. The gas becomes ionized and forms plasma that consists of negatively and positively charged particles and that generates an intense white light when an electrical current is passed through the xenon. They offer 1200 to 1500 mW/cm² intensity and of 380 to 495 nm wavelength range. Due to its high intensity, manufacturers declared that one to three seconds of plasma irradiation cures many resin composites to hardness in comparison with 40 seconds of halogen light cure [13].

To overcome the disadvantages of halogen visible light, the solid-state light emitting diode (LED) technology was recommended [14,15]. LEDs use junctions of "doped" semiconductors to generate light instead of the hot filaments used in halogen bulbs [11].

LEDs had many advantages over other types of light cures; it offered relatively short time to polymerize composite, long life time reaching 10,000 hours [14], undergoing little degradation of output over this time, minute quantity of wasted energy, least amount of heat generation, consuming little power, can be run on rechargeable batteries, had lightweight ergonomic design [16], combined high power output (1000 mW/cm²) with a very narrow wavelength range of about 450-490 nm which matches well with the absorption peak of camphoroquinone [17], did not need filters to produce blue light, resistant to vibration and shock [14] and finally, compressive strength, flexural strength, or modulus were proved to be comparable

between composite cured by halogen and LED light cure unite [18].

The aim of this study was to evaluate the effect of reducing the light curing time to 1 and 3 seconds using i-LED light curing unit on the shear bond strength of stainless steel orthodontic brackets bonded to teeth in comparison with light exposure of 40 seconds from a conventional halogen-based light-curing unit which was used as a control.

2. Materials and Methods

Sample

1. Thirty human maxillary first premolars extracted for orthodontic purposes were selected, after careful cleaning and examination with 10X magnifying lens [19], having normal buccal surface with no crack, caries or immersion in hydrogen peroxide [20]. These teeth were stored at room temperature in closed container containing tap water that was changed daily to prevent the dehydration and microbial growth.
2. Thirty standard edgewise premolar brackets (Ortho technology Co., USA) with surface area of 10.9 mm².

3. Methods

Retentive wedge-shaped cuts were made on the root surface of the teeth to increase their retention inside the acrylic block [21,22]. The teeth then fixed on glass slide using sticky wax at the apical root area so that the middle third of the buccal surface was placed parallel to the analyzing bar of the surveyor. In this way, the buccal surface kept parallel to the force applied during testing [20] (Figure 1).

The teeth were fixed in self cured acrylic using two L-shaped metal plates painted with Vaseline placed opposite to each other to form a box around the teeth [23] (Figure 2). After acrylic setting, the two L-shaped metal plates were removed and the wax at the root apex was removed and replaced with acrylic, then the acrylic blocks were adjusted with bur to set properly in the testing machine (Figure 3). After that, the specimens were stored in normal saline solution to prevent dehydration until bonding [24].



Figure 1: Orienting the teeth prior to their fixation using surveyor



Figure 2: The two L-shaped metal plates in position forming a box around the teeth



Figure 3: Mounted teeth

At the day of bonding, the teeth were polished with non-fluoridated pumice and prophylactic rubber cups for 10 seconds washed with water spray for 10 seconds and dried with oil-free air for 10 seconds.

The buccal surface was etched with Ormco acid etch solution (Lot No. 16J1, Ormco, USA) for 30 seconds, rinsed with water spray for 5 seconds and dried with oil-free air for 10 seconds till getting chalky appearance.

According to manufacturer instruction, a very thin coat of Ortho Solo™ (Lot No. 6122747, Ormco, USA) was applied by brush on each tooth surface to be bonded. Grengloo™ adhesive paste for metal brackets (Lot No. 6096063, Ormco, USA) was extruded on the pad and small amount of it was placed on the brackets back using plastic adhesive applicator from Ormco.

The brackets were centered on the buccal surface of the teeth. For standardization of the force applied on the brackets during bonding, a load of 300g applied to the vertical arm of the surveyor was used [25]. The excess of adhesive was then removed from around the bracket using sharp probe.

The teeth were divided into three equal groups each with ten teeth bonded in the same manner with one exception.

1. Group I: Ten teeth were bonded and light cured using Ortholux XT Light-Curing Unit (3M Unitek) for 40 seconds (20 seconds from mesial and distal surfaces). Ortholux is a halogen light with intensity reaching up to 300mW/cm².
2. Group II: Ten teeth were bonded and light cured using Woodpecker i-Led (intensity is 2300mW/cm², Woodpecker, China) from the incisal direction for 3 seconds.

3. Group III: Ten teeth were bonded and light cured using Woodpecker i-Led (intensity is 2300mW/cm², Woodpecker, China) from the incisal direction for 1 second.

The distance between the light cure tip and bracket edge was zero mm. [26,27] and during bonding of one tooth, the other teeth were covered with polishing ring to prevent the light from reaching the bonded tooth/teeth [28].

The bonded teeth were left for an hour undisturbed, and then the acrylic blocks were stored in water for 24 hours preparing for testing (Figure 4). Using Instron universal testing machine with a crosshead speed of 0.5 mm/minute [29], the samples were tested for shear bond strength (Figure 5). The force recorded for debonding the brackets was divided by the brackets surface area to get the shear bond strength in Mega Pascal.



Figure 4: Teeth were bonded

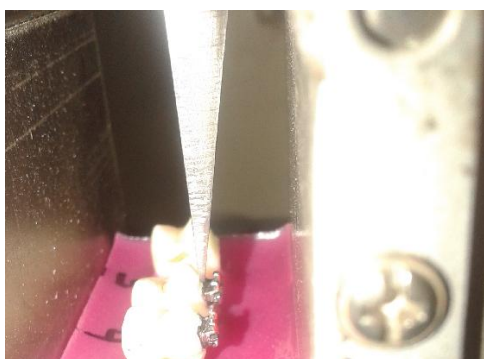


Figure 5: Debonding the brackets

The adhesive remnant index was estimated after careful examination of the brackets and the tooth surfaces using stereomicroscope with a 20X magnification. The site of bond failure was scored according to Wang *et al.* [30] and as follows:

Score I: The site of 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 analyses

Data were analyzed using SPSS software version 21. The following statistics were used:

- a. Descriptive statistics: including means, standard deviations, frequency 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 three curing times groups.
 2. Tukey's honestly significant difference (HSD): To test any statistically significant differences between each two groups when ANOVA showed a statistically significant difference among the groups.
 3. Chi-square: To test any statistically significant differences between the groups for the failure site examination results.

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

Non-significant	NS	$P > 0.05$
Significant	S	$0.05 \geq P > 0.01$
Highly significant	HS	$P \leq 0.01$

4. Results

Table 1 showed the descriptive statistics and groups' difference for the shear bond strength. The highest shear bond strength was recorded in the group of iLED 3 seconds followed by 1 second then the halogen light group. One way ANOVA test showed statistically high significant group difference.

Tukey's HSD test revealed high significant difference between halogen group and iLED 3 seconds group, while there was non-significant difference between the other groups.

Table 2 illustrated the frequency distribution and percentage of the adhesive remnant index scores of all tested groups. For halogen light and iLED 3 seconds' groups, the predominant scores were II and III, while in iLED 1 second group, score I and III were predominant. Score IV was not recorded in any group.

Pearson's Chi-square test revealed non-significant difference among the groups.

Table 1: Descriptive statistics, ANOVA then Tukey's HSD test for shear bond strength (SBS) according to light types

Descriptive statistics				Group difference						
Types of light		Halo gen	i-LED		ANOVA test			HSD test		
Time (sec.)		40	3	1	F-test	d. f.	P-value	40-3	40-1	3-1
SB	Me	4.56	8.2	6.4	9.5	2	0.001	0.00	0.0	0.0
	an	6	31	26						
(M Pa)	S.	1.64	2.1	1.8	11	9	(H)	(H)	(N)	(N)
	D.	9	20	39						

Table 2: Scores of Adhesive Remnant Index and chi square test among the groups

Scores	Types of light cure			Comparison		
	Halogen 40 sec.	i-LED		χ^2	d.f.	p-value
		3 sec.	1 sec.			
I	1 (10%)	1 (10%)	4 (40%)	4.875	4	0.300 (NS)
II	4 (40%)	3 (30%)	1 (10%)			
III	5 (50%)	6 (60%)	5 (50%)			
IV	0 (0%)	0 (0%)	0 (0%)			

5. Discussion

Throughout the course of fixed orthodontic appliance treatment, the brackets will be under stress from archwires and masticatory forces, so orthodontists must give awareness to attain suitable bond strength to avoid brackets debonding.

Results in the present study were incomparable with other studies due to the difference in the brackets surface areas, adhesive used, light cure intensity and curing time.

The shear bond strengths of the LED groups lie within the limit reported by Reynold [31] between 6-8 MPa while for halogen group, it was less than this limit (Table 1). Statistically, there was high significant difference among the studied groups. Tukey's HSD test revealed high significant difference between the halogen group and 3 seconds LED group only, while non-significant difference was reported between the other groups.

Many studies compared QTH and LED and reported no significant difference in shear bond strength [4,32-36], while others [37-39] reported differences between the two systems.

In reviewing table 2, there was non-significant difference among the tested groups with the most reported scores were 2 and 3 like other studies [8,34,35,37,38], so the bonding failure occurred between the bracket and the adhesive or at the adhesive interface. This indicated that the adhesive was incompletely polymerized at the brackets base due to squat time of light exposure [37,40] for the LED groups, i.e. most of the adhesive remained on the buccal surface of the tooth so it can be removed easily without enamel damage.

The bond strength depended on the curing time, light cure power, total energy released, distance between the light cure tip and bracket and bracket types.

Studies [37,40-43] reported that, there was direct relation between increasing the time of curing with shear bond strength. This was attributed to higher rate of monomer/polymer conversion occurred with increasing curing time.

The second factor is the light cure power. It affected the level of polymerization of adhesive. When the light power is high; there will be greater numbers of photon that reached the composite and higher number of free radicals that convert monomer into polymer [37]. In the present

study, the curing power of halogen light cure was 300mW/cm², while for LED, it was 2300mW/cm².

Reviewing the absorption curve of camphoroquinine, it extended from 360 to 520 nm and the maximum at 465nm. At this range, the most favorable emission band width of the light source stood between 450 and 490 nm. With halogen light, the main part of photons was emitted outside this range, so these photons failed or had little chance to be absorbed by camphoroquinine [38]. This explains the reduced shear bond strength of halogen light cure group. For the LED groups, fortunately 95% of the emission spectrum lay between 440 and 500 nm [8] that is considered nearly the same to the absorption peak of camphoroquinie. Although the higher light intensity of LED groups, the energy supplied was inadequate due to short light exposure.

Other factor is the distance between the light cure tip and bracket. Studies [26,27] found that whenever the distance increased, the bond strength lessen. Two and four mm. distance [44] did not affect the bond strength. In this study, the distance was zero.

Lastly, the bracket types, metal brackets unlike ceramic or sapphire one necessitated transmission mechanism afforded by reflection from the tooth structure. As the distance between the light unit and the bracket edge is approximate, the tooth surface will reflect the light onto the adhesive system under the bracket. This absorption and reflection procedure will reduce the intensity of light and the quantity of energy transport to the adhesive. So the short exposure explained the reduced bond strength of LED groups especially one second group.

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