Original Article

Effect of Fast Curing Lights, Argon Laser, and Plasma Arc on Bond Strengths of Orthodontic Brackets: An *In Vitro* Study

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Abstract:

Objective: Nowadays light-cured composites are used widely by orthodontists to bond brackets. As these composites require 20-40 seconds time per tooth to be light cured, more chair-time in needed compared to self-cured composites. In recent years, the argon laser and plasma arc lights have been introduced in dentistry to reduce this curing time. The purpose of this study was to compare bond strength of brackets bonded with the argon laser and plasma arc light with those bonded with the conventional halogen light.
Materials and Methods: Fifty-one intact human premolars were randomly divided into three groups of 17 teeth each. Stainless steel twin premolar brackets (018- in Dyna lock, 3M Unitek) were bonded to the teeth using one of these curing devices in each group: the halogen unit (Coltolux 75, Switzerland), the argon laser unit (Bo-5, Iran), and the plasma arc unit (Remecure 15, Belgium). The orthodontic adhesive was the same in the three groups (Transbond XT, 3M Unitek). After thermal cycling, the diametral tensile bond strength of specimens was measured using a debonding plier in a Zwick Universal Testing machine (Z/100, Germany).
Results: The mean bond strengths was 17.344 MPa (SD=4.567) for halogen 19.172 MPa (SD=6.328) for laser and 19.322 MPa (SD=4.036) for plasma arc groups. No statistically significant difference existed in the mean bond strengths among three groups.
Conclusion: Argon laser lights, significantly reducing the curing time of orthodontic brackets without affecting bond strength, have the potential to be considered as advantageous alternatives to conventional halogen light.

Key Words: Tensile Strength; Orthodontic Brackets; Curing Lights, Dental; Lasers

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INTRODUCTION

Visible light-cured (VLC) adhesives have become increasingly more popular to bond orthodontic attachments because they offer several advantages over chemically cured adhesives. These advantages include ease of use, extended working time, improved bracket placement and easy clean up of excess adhesive [1]. On the other hand, the major disadvantage of these adhesives is the 20 to 40 seconds light curing time for each bracket [2]. The most common initiator used in VLC adhesives is camphorquinone that reaches peak absorption at a wavelength of approximately 470 to 490 nm [3]. Most tungsten-quartz halogen lights produce an energy density of approximately 400 mW/cm^2 with a broad bandwidth of 400 to 520 nm.

The first try to decrease curing time was undertaken in the late 1980s with argon laser. The argon laser produces a highly concentrated coherent beam of light centered around the 480 nm wavelength and with an intensity that approaches 800 mW/cm^2 [3,4]. Although it has been suggested that such short laser light exposure time as 5 seconds produces a bracket bond strength equal to 40 seconds exposure to conventional tungsten-quartz halogen light [5], most studies recommend 10 seconds of laser light exposure [2,6-8].

In the late 1990s, a new type of light produced in a xenon plasma arc bulb was introduced. The light source is a xenon gas that is ionized by two electrodes with a large voltage potential to produce plasma [3]. The emitted white light is filtered to a bandwidth of 450 to 500 nm, and the power density can reach more than 2000 mW/cm^2 [4]. Claims of exposure times as short as two seconds per bracket were made [3,4,9-11], but most reports claimed exposure times of 3 to 6 seconds for metal brackets [1,3,4,12-18], and 3 seconds for ceramic brackets [19]. This reduced bonding time with each of these two lights have a number of advantages such as increased comfort for the patient, less probability of bracket drift prior to curing, less time for moisture contamination, less stress for the operator, and cost saving by reducing surgery time [18]. Great numbers of orthodontist prefer to use halogen light instead of plasma arc because of the probability of non-complete curing of bonds due to fast curing. Therefore, there is a controversy about the use of plasma arc for curing of bonds.

The present study evaluated the efficiency of a xenon plasma arc light versus a conventional tungsten-quartz halogen light and a fast-curing argon laser in producing sufficient bond strength for orthodontic brackets.

MATERIALS AND METHODS

Fifty-one intact human premolars extracted for orthodontic purposes were collected in an aqueous solution of thymol (0.1 % wt/vol). The teeth were cleaned with a brush and water slurry at low speed without using pumice. We then examined the teeth under illumination and x10 magnification to exclude the teeth with enamel fractures or defects. The teeth were randomly divided into three groups of 17 teeth each. Stainless steel twin premolar brackets (018- in Dyna lock , 3M Unitek) with base surface area of 13.10 mm^2 were bonded to the teeth using one of these curing devices in each group: the halogen unit (Coltolux 75, Switzerland), the argon laser unit (Bo-5, Iran), and the plasma arc unit (Remecure 15, Belgium). The orthodontic adhesive (Transbond XT, 3M Unitek) was the same in the three groups.

One operator (HMH) prepared the teeth and bonded the brackets to them according to the following protocol:

1. The teeth were acid-etched for 15 seconds with 37% phosphoric acid (3M Unitek, Monrovia, Calif)) according to composite manufacturer instructions;
2. The teeth were rinsed at least for 15 seconds with an air-water syringe;
3. The teeth were dried with an air-water sy-

Table 1. Mean bond strength of the brackets bonded under halogen, plasma arc using argon laser.

Group	N	Mean (SD)	SE	Confidence Interval (95%)		Min	Max
				Lower bound	Upper bound		
Halogen	17	17.344 (4.567)	1.107	14.994	19.693	9.32	25.86
Plasma arc	17	19.322 (4.036)	0.979	17.246	21.397	14.17	26.16
Laser	17	19.172 (6.328)	1.489	16.019	22.302	7.09	27.97

SD=Standard Deviation, SE=Standard Error, Min=minimum, Max=maximum ringe to produce frosty appearance;

4. The teeth were coated with primer (Transbond XT, 3M Unitek, Monrovia, Calif) thinned with a puff of air from the air-water syringe;

5. By a manual Dontrix gage and under 250 gr force, the adhesive-loaded brackets were placed on the middle of mesiodistal width of the teeth on the buccal ridge, along the long axis of teeth and 4 mm under the tip of buccal cusp. Any excess adhesive was removed.

6. The adhesives were cured according to following exposure times: halogen light group: 10 seconds mesially and 10 seconds distally (20 seconds total), argon laser group: five seconds mesially and five seconds distally (10 seconds total), and plasma arc group: three seconds mesially and two seconds distally (five seconds total).

Light intensity of halogen unit, recorded with halogen light meter (Apoza, Taiwan), was 500 mW/cm^2. Power of light emitted from argon laser unit was measured with a power-meter that was calibrated with an American coherent power meter (Coherent Ltd, Cambridge, UK). The laser light intensity, calculated by dividing power of light by focal spot area (4.5 mm^2), was 850 mW/cm^2. The halogen light meter was used to measure light intensity of plasma arc light since no specific device was available. After bonding, all samples were stored in distilled water at room temperature for 24 hours. In order to simulate accelerated aging by thermally induced stresses thermal cycling was performed with 1500 repetitions between 10˚C and 55˚C, and 30-second well time in each bath. Then tensile bond strength of specimens were measured with Bishara's method [20] by bracket removal plier (I 00545, narrow blades, RMO, USA) in a Zwick Universal Testing machine (Z/100, Germany) with a load cell of 50 KN and crosshead speed of 1 mm/min in mesiodistal direction (Fig 1). After debonding, the teeth were examined under magnification of x 50. Any adhesive remaining after bracket removal was assessed according to the adhesive remnant index (ARI). The ARI scale ranges form 5 to 1, with 5 showing that no composite remained on the enamel; 4, less than 10% of the composite remained on the tooth surface; 3, more than 10% but less than 90% of the composite remained; 2, more than 90% remained on the tooth, and 1, all composite remained on the tooth, along with the impression of the bracket base [21].

Statistical analysis was performed with SPSS software. Normal distribution in the groups was assessed with one-sample Kolmogorov-Smirnov test was used to evaluate the distribution of the data in the groups. Homogeneity of variances in the groups was statistically tested, and one-way analysis of variance of variance (ANOVA) was used to compare bond strength among groups. ARI data was analyzed with Kruskal-Wallis test.

RESULTS

After debonding three incidences of named fracture were observed, two occurred in halogen group, and one in plasma arc group. Also there two incidences of enamel crack; one in halogen group and one in plasma arc group were appeared. No enamel fracture or crack in laser group existed.

Table 2. Absolute and relative frequency of ARI of the brackets bonded under the study conditions.

Group	ARI Index Scores					Total
	1	2	3	4	5	
Halogen	0 (0.0%)	0 (0.0%)	3 (17.6%)	13 (76.5%)	1(5.9%)	17 (100.0%)
Plasma arc	0 (0.0%)	1 (5.9%)	5 (29.4%)	8 (47.1%)	3 (17.6%)	17 (100.0%)
Laser	2 (11.8%)	0 (0.0%)	3 (17.6%)	8 (47.1%)	4 (23.5%)	17 (100.0%)
Total	2 (3.9%)	1 (2.0%)	11 (21.6%)	29 (56.9%)	8 (15.7%)	51 (100.0%)

ARI=Adhesive Remnant Index

Fig 1. Zwick Universal Testing machine (Z/100, Germany) with a load cell of 50 KN and crosshead speed of 1 mm/min in mesiodistal direction.

One-sample Kolmogorov-Smirnov analysis showed that the distribution of data within all three groups was normal (P>0.05). The variances in the groups were also homogeneous (P>0.05). Bond strength were 17.344 MPa (SD=4.567) in halogen group, 19.322 MPa (SD=4.036) in plasma arc group, and 19.172 MPa (SD=6.328) in laser group. ANOVA test showed that no statistically significant difference existed in bond strengths among the groups (P>0.05) (Table 1). Comparison of ARI data with Kruskal-Wallis test showed that no significant statistical difference existed among groups (P>0.05) (Table 2).

DISCUSSION

The mean bond strengths of all groups in the present study far exceeded the suggested minimum bond strength (6 to 8 MPa) for clinical orthodontic treatment [22,23]. In addition, all mean bond strengths were greater than those recommended by Retief [24] to avoid enamel damage. Occurrence of enamel damage in three samples of halogen group and two samples of plasma arc group may be due to these high bond strengths. These results resemble to findings from another study in which mean bond strength of metal brackets bonded with halogen light and measured with Bishara's method was 20.732 MPa [25]. Anyway, clinically, intraoral contamination, moisture, temperature, and other forces such as masticatory forces, trauma, and orthodontic mechanics can influence bond strength. Thus, the clinical bond strength may be lower than that obtained in the present study [12]. In laser group there was no enamel damage. It seems further study is needed about bracket bonding with laser and enamel damages during debonding.

James et al [1] compared bond strength of brackets bonded with Transbond XT and three lights of halogen, plasma arc and argon laser with light exposure times similar to our study. Their results showed that bond strengths in halogen and plasma arc groups were more than laser group. Moreover, mean bond strengths in halogen and laser groups were lower than minimum bond strength recommended by Reynolds [22] and their results differed considerably from our findings [1]. This difference may be due to difference in type of brackets, light intensity (laser light intensity was 238 mW/cm^2), and debonding with a lower crosshead speed (0.1 mm/min).

Exposure times as few as two seconds exposure to plasma arc [9-11] and five seconds exposure to argon laser light [5] have been recommended for metal brackets. However, some studies showed that a minimum of 3 to 6 seconds exposure to plasma arc is needed to produce bond strengths comparable with 20 [1,4,12,14,16-18] or 40 seconds exposure to a conventional tungsten-quartz halogen light. Moreover, most studies recommend 10 seconds of exposure time for argon laser light [2,6-8]. Thus, five-second exposure to plasma arc light and 10 seconds exposure to argon laser light was performed in the present study.

Comparable bond strengths between halogen and plasma arc groups, and also between halogen and laser groups in the present study is in line with findings from some previous studies [2-4,12,13,15-17]. Some other studies on comparison of 10 seconds laser and 40 seconds halogen exposure also have reported similar results to our study [5-8].

ARI is not affected solely by bond strength and a number of other factors have been found to influence the ARI score including bonding procedure, debonding technique, and bracket base design [16]. However, ARI has clinical importance because the less adhesive remained on the tooth, the more stress affecting enamel surface [20]. In the present study, no statistically significant difference existed among the groups regarding the ARI scores. Similar ARI scores in halogen and plasma arc groups in present study is consistent with findings from some previous studies [3,10,14,16,19]. Similar ARI scores in halogen and laser groups also are in line with findings of Lalani et al [5].

Some concerns have been expressed with regard to the use of high-intensity lights. One of these concerns is the heat generated by the intense light and the effect of heat on the dental pulp. The short duration of the light, as well as changing the location of the light, decreases any pulpal temperature effects to a minimum [3]. Another concern is the shrinkage of the resin caused by the rapid curing with the high-intensity lights. In bonding orthodontic brackets, there is several factors different form those in restorative dentistry applications. First, the adhesive layer is very thin. Second, usually an excess of resin exists at the edges of the adhesive area to absorb some of the shrinkage. Third, the bracket is free floating and shrinkage would pull the bracket closer to the enamel, which is probably an advantage rather than a disadvantage. Thus, in orthodontic applications resin shrinkage is probably not a concern [3].

A further concern with the new high-energy lights is matching the wavelength of the light to the wavelength required to activate polymerization in the composite resin. This appears to be a minor concern, since most dental composite resins including orthodontic adhesives use comphorquinone for photo initiators. Moreover, the manufacturers must notify the clinicians of their specific light requirements [3].

CONCLUSION

The present study shows that plasma arc and argon laser lights, significantly reducing the curing time of orthodontic brackets without affecting bond strength, have the potential to be considered as advantageous alternatives to conventional halogen light.

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