Shear bond strength of orthodontic brackets: a comparison of self-cure techniques using various light sources

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Abstract:

Aim: Light cure composites are routinely used to attach orthodontic brackets, so bond strength and cure time must be considered. However, the disadvantages of the conventional halogen apparatus include heat and lengthy composite curing. Therefore, the purpose of this study was to compare shear bond strength of orthodontic brackets composite cured by plasma arc (PAC), conventional halogen (QTH), light- emitting diode (LED) and self-cure.

Materials and Methods: In this in vitro study, sixty premolar teeth extracted for orthodontic purposes from patients under 18 years of age were collected and divided into four equal groups. In the first group, the brackets were bonded by self-cure composite. In the second, third, and fourth groups, they were bonded by halogen, LED and plasma arc, respectively. The samples were thermocycled and finally the force required for brackt failure was measured. Shear bond strength was obtained by dividing the exerted force by the bracket base surface. ARI (Adhesive Remnant Index) and EDI(Enamel Detachment index) were also evaluated. Data were analyzed by ANOVA followed by TUKEY test.

Results: Average shear bond strengths were 14.7±5.4 MPa in the self–cure group, 14.6±5.3 MPa in the halogen group, 14.7±4.5 MPa in the LED group, and 14.2±5 MPa in the plasma group. There were no significant differences among the groups. EDI and ARI did not differ between the light-cure and self-cure groups.

Conclusion: No significant difference was observed in shear bond strength among different methods of composite curing. Therefore, despite the high cost of plasma arc, it is recommended in order to reduce operation time.

Keywords: Self-cure, halogen cure, LED and plasma arc apparatus, shear bond strength.

(Received May 14, 09; Revised and accepted Jan 16, 10)

In fixed appliance treatment, one of the most important requirements is correct bracket positioning.[1] The use of light-cured adhesives has become popular since they provide increased working time[2] and aid in correct bracket positioning. The use of light-cured adhesives in orthodontics was first reported by Tavas and Watts.[3]

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Unfortunately, as a result of conflicting reports comparing the bond strengths of light- and chemically-cured adhesives,[4, 5, 6] the use of light-cured products is not as widespread in orthodontics as in restorative dentistry. However, the disadvantage of the conventional halogen apparatus is that only 1% of the total energy input is converted into light, while the remaining energy is given off as heat. The short life of halogen bulbs and noisy cooling fan are other disadvantages.[7] The main advantage of light-cured adhesives is the 'command setting'. However, this is also a disadvantage since the

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time required to initiate polymerization with a light source may seem inconvenient to clinicians. To reduce the bonding time, pre-coated brackets have been developed. These brackets have been shown to perform satisfactorily in clinical situations.[8] Also, to this end, new curing light technologies have been developed, which manufacturers claim reduce the curing time by one third to one half relative to conventional tungsten-quartz-halogen bulb light-curing sources. However, bond strength depends on factors such as appropriate technique and high-quality materials and apparatus.[9]

In a study by Penido [10], The type of light-curing unit did not interfere with the results of the mechanical tests in vivo or in vitro. Jaundt[11] found the same curing depth and pressure strength in composites cured by LED and conventional halogen. Turkkahraman.[12] did not find any difference in failure between brackets bonded by LED or halogen in an in vivo study. Sfondrini [13,14], Kloche[15] and Thind[16] did not report any difference in bond failure between groups bonded by LED (20 s) and plasma arch (5 s).

The main aim of this study was to compare the debonding stress for brackets bonded with the same light-cured adhesive system but cured with light sources that utilize different technologies for light production and self-cure composite. The second aim was to evaluate the bond failure site.

Materials and Methods

Sixty first upper premolars without cracks or decay were pulled out through orthodontics, then divided into four groups with 15 samples. After being gathered and washed with water and soap, samples were stocked in physiologic serum. A standard edgewise premolar steel bracket (018 standard, Germany Dentarum Company) was used, in combination with representative examples of conventional tungsten-quartz-halogen (QHT), plasma arc (PAC) and light-emitting diode (LED) bulbs:

Astralis7, a QHT bulb source with an irradiance of 400 mWcm–2,emitting light in the range of 400–500 nm.

Ortho lite, a plasma arc source with an irradiance of 2000 mWcm–2, emitting light in the range of 400–500 nm.

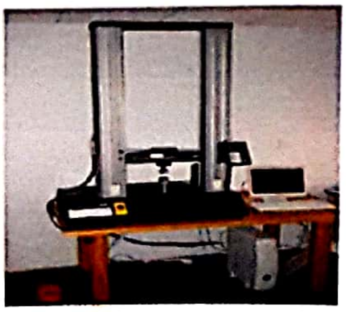
Ultralume2, a blue LED source with an irradiance of 1000 mWcm–2, emitting light in the range of 430–480 nm.

A single clinically experienced operator carried out all bonding. The materials were used according to the manufacturer's instructions: the teeth were pumiced using fluoride-free pumice and water for 15 seconds applied with a rubber cup, then rinsed with water and dried in a stream of compressed air. The teeth were then etched for 15 seconds with 37% phosphoric acid, washed with water for 20 seconds and dried using compressed air. A thin layer of primer was applied to the etched tooth surface with a microbrush. The bracket was loaded with adhesive and placed on the buccal surface with light pressure (~250 g force) to extrude any excess adhesive, which was removed with a probe. The adhesive was cured using the times recommended by the manufacturer for each light source. In the first group, brackets were bonded using self-cure composites of Resilience; in the second, third and fourth groups, they were bonded using Resilience light-cure composite.

Halogen-group samples were cured for 20 seconds; LED samples were cured for 10 seconds; PAC samples were cured for 3 seconds. For tooth fixation, we created a cylinder with 23-mm internal diameter, 25-mm height and edges parallel with the horizon(figure1).

Then, a 17× 25 wire was placed in the slot of each bracket and fixed by soft wire. Next, bracket and tooth were placed in the cylinder. Soon after the wire was tangent with the cylinder edge, semi-liquid acryl was injected around the tooth(figure2).

The samples were thermo-cycled after one day between 5 and 55° C as follows: 30-second warm bathing, 55°C; 20-second interval; and 30-second cool bathing (5°C). The brackets were separated from the tooth surface by Hounsfield mechanical testing machine, H10KS model, made in England with 0.5 mm/min velocity. The force required for their separation was measured (figure3).



By dividing this force by bracket surface area (10.87 m), shear bond strength (SBS) was determined. Then, samples, tooth, and separated bracket were studied by light microscopy with a magnification of 10X. ARI (Adhesive Remnant Index) was recorded with regard to Bishara's suggested index.[17]

Scale 1: all the composite remained on the tooth
Scale 2: more than 90% of the composite remained on the tooth
Scale 3: more than 10% but less than 90% remained on the tooth
Scale 4: less than 10% remained on the tooth
Scale 5: no composite remained on the tooth

EDI (Enamel Detachment index) was also studied. In the PAC and LED groups, each had lost one sample before strength was measured. Statistical analyses were performed with the ANOVA and TUKEY tests.

Results

The mean SBS and force for samples in different groups were not significantly in different groups (table 1), and the Tukey test also didn't significantly differ between groups (P>0.05). Table 2 shows that ARI in the light-cure and self-cure groups had no statistical significant difference .Among the LED, PAC and QTH groups, the third scale of ARI was most frequent. EDI did not differ between the light-cure and self-cure groups.

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Variable	Force (N)			SBS (MPa)		
Groups	Min-Max	Mean ± SD	P-value	Min-Max	Mean ± SD	P-value
LED (n=14)	94.7 – 253.4	167.1 ± 48.4	0.962	8.6 – 23.2	15.3 ± 4.4	0.962
QTH (n=15)	82.3 – 253.3	159.2 ± 58.6		7.5 – 23.1	14.5 ± 5.3	
PAC (n=14)	83.1 – 248.1	156.2 ± 55.7		7.6 – 22.7	14.3 ± 5.1	
SELF (n=15)	81.2 – 260.3	160.4 ± 59.2		7.4 – 23.8	14.6 ± 5.4	

Table 1: The mean (±SD), maximum and minimum of strength and bond strength in the different groups

SELF (n=15) Frequency (%)	PAC (n=14) Frequency (%)	QTH (n=15) Frequency (%)	LED (n=14) Frequency (%)	Group Scale
3 (20)	2 (14.3)	1 (6.7)	0 (0)	1
7 (46.7)	0 (0)	2 (13.3)	4 (28.6)	2
4 (26.7)	9 (64.3)	9 (60)	9 (64.3)	3
1 (6.7)	3 (21.4)	3 (20)	1 (7.1)	4
0 (0)	0 (0)	0 (0)	0 (0)	5

Table2: The distribution of ARI in the different groups.

Discussion

There was no statistical difference in debond stress among the four groups. Orthodontists are mainly concerned with minimum bond strength, below which a bond between the tooth and bracket is too weak to withstand forces applied to it during treatment. This minimum level is difficult to calculate due to the large variations in forces (for example, from different arch wires or from mastication) that a bracket has to endure over the course of an average orthodontic treatment. It has been suggested that a minimum bond strength of 5.9-7.8 MPa should be adequate for most clinical orthodontic needs.[18] According to this minimum requirement, all four light sources cured the adhesive to an equally satisfactory level. If, in clinical practice, the survival rate is satisfactory for brackets bonded to enamel by adhesive that is cured using light from a conventional tungsten-quartz-halogen source or self cured, then the results obtained with plasma arc and LED sources should be equally satisfactory.

Since enamel is a brittle material, a fracture mechanics approach should be adopted. By directing the fracture pathway along the enamel/adhesive interface, the potential presence of defects in the enamel and high force (due to an effective bond) will increase the risk of enamel fracture. It has been recommended that the tensile bond stress should not exceed 14.5 MPa if enamel fracture is to be avoided. There are no equivalent recommendations for an upper shear bond stress limit.[19]

In the present research, shear bond strength of brackets bonded by different composites and curing methods was studied. SBS (MPa) in the first group, in which brackets were bonded by self-cure composite, was 14.7±5.4 MPa. In the second group, SBS was 14.6±5.3 MPa; in the third group, it was 14.7± 5.4 MPa; and in the fourth group, it was 14.2±5 MPa. There was no

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significant difference between groups (p=0.96) (Table 1).
In the group with the self-cure composite, the most frequent failure in bracket separation was between the surface bracket and the resin surface. With the light-cure composite, the most frequent failure was between the enamel surface and resin, probably because of composite contraction. Similarly, with the light-cure composite, the direction of contraction was towards the bracket, whereas with the self- cure brackets, it was towards the tooth surface.[20]
The time recommended for curing the adhesive was shortest with the plasma light and longest with the conventional QTH curing light. a shorter curing time may also reduce the risk of saliva contamination and further reduce the incidence of bond failure.[16] In agreement with our results, Signorelli found no significant difference in shear bond strength between brackets bonded with QTH-cured composites cured for 30 seconds and plasma arc-cured composites cured for 3 and 6 seconds.[21] However, Tolendo found the highest SBS in self-cure composites.[22]
Birkam et al. in 2005 did not report any significant difference in strength between brackets bonded by halogen (20 seconds), LED (10 seconds) and plasma arc (6 seconds). However, plasma arc was suggested to reduce processing time.[23] Staudt (2006) found no significant difference in shear bond strength between brackets bonded by LED (20 seconds) and QTH (40 seconds).[24]
In studies by others, the shortest time (3 seconds) was reported for plasma arc curing,[15,16,21,25,26] as in the current study. In this study, no significant difference in bond strength was obtained between the PAC, halogen, LED and self–cure groups. In using self-cure composites, the most frequent failure in bracket separation occurred at the bracket-resin interface. In light-cure composites, the most frequent failure occurred at the resin-enamel interface. There was no significant difference in the frequency of failures in the LED group. Therefore, two kinds of composites can be used for the purpose of enamel health. Due to the short processing time, plasma arc is suggested, though it is not cost-effective. Conclusions drawn from the results of any properly constructed laboratory investigation will provide a sound basis for the clinical introduction of new products and techniques. However, it is in the nature of a controlled scientific experiment that the number of variables will be minimized through ex vivo design to allow a specific variable to be studied. It is possible to simulate conditions that are close to those in clinical use, but the potential for unrecognized factors to influence the outcome should always be borne in mind.[27]

Conclusion

The results of this ex vivo study show that all three curing lights and self-cure techniques are equally effective .but plasma arc is recommended in order to reduce operation time. However, controlled clinical studies are required for confirmation.

Acknowledgments

The authors would like to thank all employees in Shahed Dentistry Faculty's Laboratory, the Composite Ward at the Pasteur Institute, and the Pathology Ward run by the Babol Dentistry faculty.

References:

1.Bennett J C, McLaughlin R P. Orthodontic management of the dentition with the preadjusted appliance.[1] Edition. ISIS Medical Media: Oxford; 1997.

2-Sonis A L. Comparison of a light-cured adhesive with an autopolymerizing bonding system. Journal of Clinical Orthodontics.1988; 22: 730–2.

3.Tavas A, Watts D C. Bonding of orthodontic brackets by transillumination of a light-activated composite: an in vitro study. British Journal of Orthodontics.1979; 6: 207–208

4.Wang W N, Meng C L. A study of bond strength between light- and self-cured orthodontic resin. American Journal of Orthodontics and Dentofacial Orthopedics. 1992; 101: 350–354

5.Trimpeneers L M, Dermaut L R. A clinical trial comparing the failure rates of two orthodontic bonding systems. American Journal of Orthodontics and Dentofacial Orthopedics. 1996; 110: 547–50.

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6.Galindo AH R, Sadowsky P L, Vlachos C, Jacobson A, Wallace D. An in vivo comparison between a visible light bonding system and a chemically cured bonding system. American Journal of Orthodontics and Dentofacial Orthopedics. 1998; 113: 271–5.

7.Thomas M Graber, Robert L Vanars, DallJR. Orthodontic current principles and and techniques. 3rd ed. 2000; chap 12:557-77.

8.Ash S, Hay N. Adhesive pre-coated brackets, a comparative clinical study. British Journal of Orthodontics. 1996; 23: 325–9.

9. Ishikawa H, Komori A, Kojima I, Ando F.Orthodontic braket bonding with plasma light and resin reinforced glass Ionomer cements. American Journal of Orthodontics and Dentofacial Orthopedics.2001;120:58-63

10. Penido SM, Penido CV, Dos Santos-Pinto A, Gandini LG Jr, Bagnato VS. In vivo and in vitro study of the shear bond strength of brackets bonded to enamel using halogen or LED light. World J Orthod. 2009;10: 21-8.

11. Jaundt KD , Mills RW,Blakweel GB, Ashworth SH. Depth of cure and compressive strength of composites cured with blue emitting diodeo. Dent Mater.2000 ;16:41-49

12.Turkkahraman H, Kucukesmen HC. Orthodontic bracket shear bond strength produced by two high-power light-emitting dioded modes and halogen light. the AngleOrthodontist.2005;75:854-7.

13.Sfondrini MF, cassifesa V,Pistorio A.Effect of convertional and high intensity resin and resin modified glass Ionomer. American Journal of Orthodontics and Dentofacial Orthopedics. 2001;119: 30-5.

14. Sfondrini MF, Cacciafesta V, Scribante A, Klersy C. Plasma arc versus halogen light curing of orthodontucs brackets: a 12-month clinical study of bond failures. Am J Orthod Dentofacial Orthop. 2004 ; 125: 342-7.

15.Klocke A, Korbmacher HM, Huck LG, Kahl-nieke B. Plasma arc curing lights for orthodontics bonding. Am J Orthod Dentofacial Orthop.2002; 122:643-8.

16. Thind BS, Stirrups DR, Lioyd CH. A comparision of tungsten quartz halogen, plasma arc and light-emitting diode light sources for the polymerization of an orthodontic adhesiove. Eur J Orthod. 2006; 28:78-82.

17.Bishara SE, Soliman MM, Oonsombat C, Laffoon JE, Aliouni R. The effect of variation Mesh-base Design on the shear bond strength of orthodontic brackets. The Angle Orthodontist. 2004; 74:400-4.

18. Reynolds I R, von Fraunhofer J A. Direct bonding of orthodontic attachments to teeth: The relation of adhesive bond strength to gauze mesh size. Br J Orthod.1975; 3: 91-5.

19-Bowen R L, Rodriguez M S. Tensile strength and modulus of elasticity of tooth structure and several restorative materials. J A D A. 1962; 64: 378–87.

20.Fusayama T. Indications for self-cured and light-cured adhesive composite resin. J Prosthet Dent.1992;67:46-51.

21- Signorelli MD, Kao E, Nagan Pw, Gladwin MA. Comparison of bond strength between orthodontic brakets bonded with halogen and Plasma Arc curing lights: an in-vitro and in-vivo study. Am J Orthod Dentofacial Orthop. 2006; 129:277-82.

22-Tolendo M, Osorio R, Osorio E, Romeo A, Higuere B de la, Garcia-Godoy F. Bond strength of orthodontic brackets using different light and self curing cements. The Angle Orthodontist. 2003; 73:56-63.

23- Bikram ST, David RS, Charles HL. A comparison of tungsten-quartz-halogen, plasmaarc and light-emitting diode light sources for the polymerization of an orthodontic adhesive. Eur J Orthod.2006;28:78-82.

24- Staudt CB, Marvopolous A, Bouillaguet S,kiliaridis S, Krejci L. Light curing time reduction with a new high power halogen lamp. Am J Orthod Dentofacial Orthop. 2005;128: 749-59.

25-Sfondrini MF, Cacciafesta V, Scribante A,Boehme A, Jost-Brinkmann PG. Effect of light-tip distance on the shear bond strengths of resin modified glass ionomer cured with high intensity halogen light emitting diode and Plasma arc lights. Am J Orthod Dentofacial Orthop. 2006;129:541-6.

26-Usumez S,Buyukyilmaz T,Karama AI,Gunduz B. Degree of conversion of two lingual retainer adhesive cured with different light sources. Eur J Orthod.2005;27:173-9.

27-Katona T R. A comparison of the stresses developed in tension, shear peel, and torsion strength testing of direct bonded orthodontic brackets. Am J Orthod Dentofacial Orthop. 1997; 112: 244–51.

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