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Comparison of shear bond strength of orthodontic brackets bonded with halogen and plasma arc light curing

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ABSTRACT

Background: Reduced time and appropriate bond strength of brackets is one of the most important aspects of orthodontic treatments. Prolonged halogen light curing for bonding of brackets is undesirable, so the purpose of this study was to compare the shear bond strength of brackets bonded with halogen light and plasma arc system.

Materials and Mehods: This was an experimental *in vitro* study. A total of 60 intact premolar teeth were collected and divided into four groups. Stainless steel orthodontic brackets were bonded to them. In groups 1 and 2, curing was done using halogen light given for 20 seconds from two and four angles. In groups 3 and 4, curing was carried out using the plasma arc system for 6 seconds from two and four angles. The shear bond strength was recorded by Instron. The statistics of ANOVA, Tukey's test, and T-test were used in data analysis.

Results: There was a statistically significant difference in shear bond strength among the four groups (P = 0.043) and between group 1 with group 2 (P = 0.035). Yet, there was no statistically significant difference between brackets bonded with plasma arc and those bonded with halogen light or between the two groups of plasma arc.

Conclusion: Using the plasma arc system is superior to other methods due to reduced curing time. Also, since in using the halogen light system, an increase in curing periods from different angles resulted in a significant increase in shear bond strength; it is advisable to apply the halogen light from different angles.

Key Words: Halogen light, plasma arc, shear bond strength

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INTRODUCTION

The use of light cure composites for adhesion of orthodontic brackets to the enamel surface has been common in the past decades. Ordinary halogen light curing systems have been used in these cases.[1] These systems can induce the proper polymerization of light cure composites in 20 to 40 seconds of curing time.[2]

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The curing time decreased as the newer composites and light cure systems were introduced. The plasma arc curing system (PAC), a system with high light intensity, was first introduced by Cacciafesta in orthodontics.[3] In this system, light is emitted from an electricity-conductive gas (plasma) which is placed under pressure between two Tungsten electrodes. The PAC lamp has a narrower spectrum of 430 to 490 nm[4] and much higher light intensity of 1 200 to 2 200 mw/cm^2, so the curing time is significantly reduced.[2] In light curing time studies, the appropriate curing time for composites using the plasma arc system has been recorded as 1,[5] 2,[3,6] 3,[5,7] 4,[6,8] 5,[1,9] 6,[2,3,5,7] 9,[7] and 10[6] seconds. Signorelli *et al*. reported that a plasma arc system with a curing time of 6 seconds has a bond strength and bond fracture similar to that of the halogen light cure systems with the curing time of

20 seconds.[2] Hence, some manufacturers recommend a time of 6 seconds (3 seconds of mesial curing and 3 seconds of distal curing) for the polymerization of the composite layer under the orthodontic brackets using the PAC systems.[2] On the basis of these findings, Oesterle believes that curing from two angles on the orthodontic brackets limits the amount of heat produced and reduces the pulpal damage and leads to transference of more light to the bracket base.[7] Of course, not all researchers agree on this.

1. In a 12-month study, Sfondrini *et al*.[1] investigated the causes of orthodontic bracket failure after curing by plasma arc light and halogen light curing on 83 patients. The results of this study showed that after 12 months, there was no statistically significant difference between failure rate of brackets cured with halogen system and plasma arc system in the maxilla and mandible.
2. Signorelli *et al*.[2] carried out an *in vitro* study of the shear bond strength of orthodontic brackets bonded with plasma arc and halogen. The study was done on 90 premolar teeth assigned to 6 equal groups. Stainless steel brackets were bonded to the teeth using either the halogen system of curing time of 20 seconds or plasma arc system with curing time of 2, 6, and 10 seconds through one angle curing. The results of the study revealed that plasma arc device with curing time of 6 seconds produced bond strength and fracture rate similar to that of halogen system with curing time of 20 seconds.
3. Yusoff *et al*.[10] investigated the effect of angle of the light cure tip on shear bond strength of orthodontic brackets. He bonded the orthodontic brackets to three groups each containing 30 premolar teeth with LED system for 40 seconds at curing angles of 0°, 45°, and 90°, and at the standard distance. Then, he put them under the shearing pressure to debond the brackets. The findings revealed that there was no significant difference in shear bond strength of orthodontic brackets by using LED device when curing were done at 0°, 45°, and 90°angle.
4. Oesterle[7] studied the quick curing of composites using the plasma arc compared to halogen light. Standard brackets were bonded to enamel of pig teeth with three types of orthodontic composites. The bondings were exposed to halogen light for 40 seconds and to plasma arc light for 3, 6, and 9 seconds. Bond strength of brackets was assessed 30 minutes and 24 hours after curing. The study showed that the shear bond strength of orthodontic brackets cured with plasma arc increases with curing time. However, there was no statistically significant difference between bond strength of orthodontic brackets bonded with halogen light at 40 seconds and plasma arc system at 3, 6, and 9 seconds. To reduce the excessive heat reaching the teeth, it was recommended to cure the teeth from several different angles at short curing times.

The question to be answered yet on the basis of dental literature reviewed above is: "Could similar curing times as above using several curing angles instead of mesial and distal angles via the plasma arc and halogen systems produce a different effect on the shear bond strength of orthodontic brackets?" So, the purpose of the present study was to compare the shear bond strength of orthodontic brackets bonded to enamel using the halogen light and plasma arc light at four angles instead of the conventional two angles to arrive at a more appropriate curing method accompanied by more acceptable shear bond strength for bonding orthodontic brackets.

MATERIALS AND METHODS

This was an experimental *in vitro* study in which the effect of curing methods on shear bond strength of orthodontic brackets is evaluated by using the halogen light curing method compared to the plasma arc method. In this study, considering the $P<0.05$, test power of %80, S = 3, and d = 3.1.[11] Fifteen samples were included in each of the four groups. Therefore, a total of 60 human maxillary premolar teeth were collected from the patients in need of orthodontic extraction. The sample teeth were selected according to the following criteria: intact enamel, absence of dental caries or restorations at the buccal aspect of teeth, absence of fracture line due to forceps extraction of the teeth, and absence of any chemical effects of bleaching. All the sample teeth were then brushed, the debris were removed, and were placed in normal saline solution[9] till the time of experiment. Then, all of the teeth were disinfected using 0.5% choloramine-T.[12]

The roots were then placed in self-curing acrylic resin (Dentsply Limited Weybridge/Surrey KT 15 SE/England) so that the labial aspect of their crowns was parallel to the shearing force applied by Instron device to debond the brackets. To do this, a Surveyor (BeGo, Germany) was used. To standardize the curing conditions and the possibility of light curing from the gingival area to the teeth, the acrylic resin on

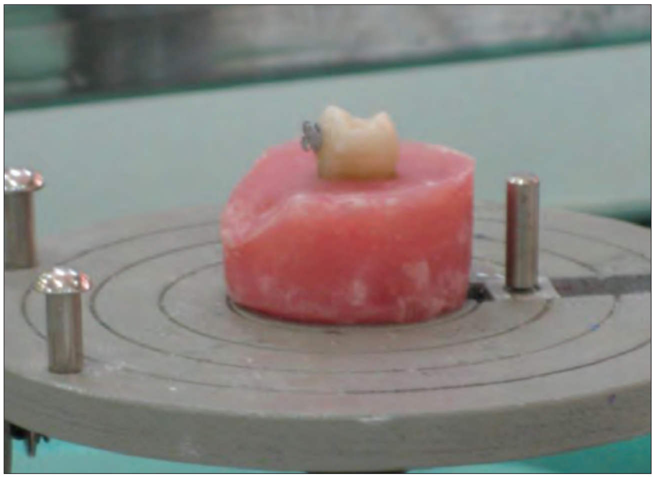

Figure 1: Acrylic resin with 45 degree angle on the buccal aspect of teeth

the buccal aspect of teeth was formed at 45 degree angle [Figure 1]. Additionally, to avoid the effect of heat due to hardening of self-cured acrylic resin, the samples passed the acrylic hardening process in water for 10 minutes. The samples were then kept in distilled water[3,7,10,13] till the time of experiment. The teeth were then assigned to four groups randomly each containing 15 samples. The curing methods for the four groups were as follows:

Group 1: Curing with halogen system using the conventional method with a time of 20 seconds (10 seconds at the mesial angle and 10 seconds at the distal angle).

Group 2: Curing with halogen system using the conventional method with a time of 20 seconds (5 seconds at the mesial angle, 5 seconds at the distal angle, 5 seconds at the gingival angle, and 5 seconds at the occlusal angle).

Group 3: Curing with the PAC system with a time of 6 seconds (3 seconds at the mesial angle and 3 seconds at the distal angle).

Group 4: Curing with the PAC system with a time of 6 seconds (2 seconds at the mesial angle, 2 seconds at the distal angle, 1 second at the gingival angle, and 1 second at the occlusal angle).

To bond the brackets, first the enamel surface was brushed with rubber cap and pumice at low speed handpiece, washed for 10 seconds, and dried with moisture-free air blow for 20 seconds. Then, the teeth were etched with 37% phosphoric acid gel (3M/USA) for 30 seconds and were sprayed with water and air for 30 seconds and finally dried.[1,5,7,11,13] Transbond XT Primer (3M Unitek, Monrovia, California, USA)[1,5,11,13] was located on etched enamel surface and formed into a thin layer via the moderate blow of compressed air. Immediately, Transbond XT Adhesive (3M Unitek, Monrovia, California, USA)[1,5,11,13] was used. Following this, orthodontic stainless steel brackets (American Orthodontic/USA) of maxillary premolars with a 12.31 mm^2 surface were put on the tooth surface. To connect the brackets, composite was first placed on the bracket base, and then using special bracket gauge, the brackets were placed on the labial surface in their correct positions. The extra composite flowing out of the bracket base was cleaned. Then, curing was done for each group according to its own curing protocol. It should be mentioned that for PAC, LiTex™ 658 (Dentamerica/Taiwan) and for halogen curing Astralis curing light (model 7 Vivadent/Lichtenstein) were used. Light intensity of each curing device was measured three times in the first second using radiometer (Dentamerica/Taiwan). The average light intensity of plasma arc system was recorded as 2 125 mw/cm^2, and that of the halogen system was recorded as 625 mw/cm^2.

Following the bonding of brackets, the groups were placed in separate glasses in distilled water[14] for 7 days. Next, the samples were exposed to shearing forces using Instron Universal Testing Machine (DARTEC/England)[2,3,5,13] operating at the cross head speed of 1 mm/minute. To do so, the exerted force was applied to the bonding site between wing and bracket base parallel to the occlusogingival plane and as close as possible to the bracket base.[3,15]

Their shearing bond strength was recorded in Newton. Then, the value for shearing bond strength in Mpa was obtained. For statistical analysis, the data collected were analyzed using the SPSS16 via the statistics of ANOVA, Tukey's test, and T-test. The P value was set at 0.05.

RESULTS

The average shearing bond strength for groups 1 through 4 were 10.77, 16.25, 12.13, and 13. 85 Mpa, respectively [Table 1].

On the basis of ANOVA, there was statistically significant difference between the compared groups (P = 0.043). Tukey's test showed that the shearing bond strength of group 2 (16.25 Mpa) was significantly higher than that of group 1 (P = 0.035). This increase was not statistically significant in the

Table 1: Means of standard deviation and standard error of measurement of the four studied groups in Mpa

Groups	Light source	Number	Mean (Mpa)	SD (Mpa)	SE of measurement	Least data	Most data
I	Halogen 20 (10-10)	15	10.77	3.46	0.89	7.96	16.29
II	Halogen 20 (5-5-5-5)	15	16.25	7.15	1.85	5.76	32.33
III	Plasma arc 6 (3-3)	15	12.13	2.82	0.73	6.08	16.27
IV	Plasma arc 6 (2-2-1-1)	15	13.85	6.28	1.72	5.84	30.99

P = 0.043

Table 2: Dyadic comparison of means, SDs, and significant differences of groups using Turkey test

Group1	Group J	Difference of means	SD	*P*-value	Maximal limit of bond strength	Minimal limit of bond strength
Ha^1	Ha^2	-5.49	1.96	*0.035	-10.69	0.29
	Pl^1	-1.37	1.96	0.898	-6.57	3.83
	Pl^2	-3.08	1.96	0.403	8.29-	2.12
Ha^2	Ha^1	-5.49	1.96	*0.035	0.87	10.69
	Pl^1	4.12	1.96	0.166	-1.08	9.32
	Pl^2	2.4	1.96	0.615	-2.8	7.6
Pl^1	Ha^1	1.37	1.96	0.898	-3.83	6.57
	Ha^2	-4.12	1.96	0.166	-9.32	1.08
	Pl^2	-1.71	1.96	0.818	-6.92	3.48
Pl^2	Ha^1	3.08	1.96	0.403	-2.18	8.29
	Ha^2	-2.4	1.96	0.615	-7.6	2.8
	Pl^1	1.72	1.96	0.818	-3.48	6.92

*Ha^1 = Halogen curing at the mesial and distal angles, *Ha^2 = Halogen illumination at the mesial, distal, occlusal, and gingival angles, *Pl^1 = Plasma arc curing at the mesial and distal angles, *Pl^2 = Plasma arc curing at the mesial, distal, occlusal, and gingival angles

Table 3: Comparison of means, SDs, and standard error of measurement in the halogen groups and plasma arc groups

Group	Number	Mean (Mpa)	SD (Ma)	SE of measurement
Halogen (1,2)	30	166.32	76.16	13.9
Plasma arc (3,4)	30	159.94	62.96	11.49

P = 0.725

plasma arc group [P = 0.818, Table 2].

Comparing the halogen and plasma arc groups, there was no statistically significant difference between group 2 compared to groups 3 and 4 (P = 0.166 and P = 0.615). Also, there was no statistically significant difference between group 1 compared to groups 3 (P = 0.898) and 4 (P = 0.403). By using T-test, there was no statistically significant difference in the overall comparison of halogen groups and plasma arc groups, i.e., total curing of two halogen groups and total curing of two plasma arc groups [P = 0.725, Table 3].

DISCUSSION

Today, light cure composites are available in orthodontics for bonding brackets to enamel. Halogen light cure device must cure each bracket for 20 to 40 seconds and this is very time consuming for all of the teeth. The plasma arc system has been introduced as a device with high intensity of light in recent years. This device was first proposed by Cacciafesta and then by others to replace the halogen light system.[2,3,7,10,13] The high intensity of light in this system (1 200-2 100 mw/cm^2) reduces the curing time of composites, this being the main advantage of this device over others.[1,7,16,17]

In this study, two systems of halogen and plasma arc light were used to bond the orthodontic brackets. The purpose of this study was to compare the shear bond strength of orthodontic brackets bonded to enamel in two- and four-directional curing angle and by using of the plasma arc and halogen light systems. However, Signorelli *et al.*[2] had previously asserted that shear bond strength of plasma arc with the total time of 6 seconds at two-directional mesial and distal curing was similar to that of halogen light with the total time of 20 seconds of two-directional mesial and distal curing. It should be mentioned that the plasma arc system can produce a clinically acceptable bond strength at 2 seconds[2,6] and 4 seconds,[6] yet this bond strength (specially at time of 2 seconds) is significantly lower compared to the curing at 4 seconds.[2]

In the present study, the bond strength value from first to last group was 10.76 Mpa -16.25 Mpa-12.13 Mpa -

13.85 Mpa, respectively. The ANOVA showed a statistically significant difference among the groups. In dyadic comparison of the groups, the Tukey's test showed a statistically significant difference between groups 1 and 2. On the basis of the findings of this research, it can be concluded that the four-directional curing to brackets can induce the better diffusion of light energy to the underlying area of the bracket base. In groups 3 and 4, the bond strength was higher with four-directional curing compared to two-directional curing; yet, it was not statistically significant. This, in turn, can lead to the better polymerization of composites and ultimately higher bond strength of brackets. So, increasing the curing periods from 2 to 4 and the consequent increased bond strength of orthodontic brackets are justifiable in this study.

The reported bond strength values in this study for groups 1 (halogen light system with two curing periods of 10 seconds duration) and 3 (plasma arc system with two curing periods of 3 seconds duration) are consistent with Klock *et al.*'s[3] values obtained with the same device, curing periods, and time being 11.15 Mpa for halogen light and 12.02 Mpa for plasma arc, respectively. Furthermore, in a study by Oesterle,[7] he used two curing periods of 3 seconds duration (3 seconds mesial and 3 seconds distal) with the plasma arc system and reported the obtained bond strength value as 20.7 ± 8.9 Mpa after 24 hours.

The difference in bond strength value in Klock *et al.*'s[3] and Osterle's[7] studies can be attributed to the type of composite used, i.e., Klock *et al.* [3] used Transbond XT while Oesterle used Transbond Apc.

Comparing the two halogen and the two plasma arc groups, there was no statistically significant difference among them. Our findings in this study are consistent with that of other researchers regarding bond strength values between the halogen and plasma groups.[1,7,13]

On the whole, increasing the curing periods resulted in a relative increase in the obtained bond strength values in both the halogen and the plasma arc group; yet, the bond strength mean was only higher significantly in group 2 (16.25 Mpa) compared to group 1 (10.76 Mpa), but there was no statistically significant difference between groups 3 and 4. The increased shear bond strength due to more curing periods in the halogen group is justifiable; the cause may be the fact that the 20 seconds period of curing time of halogen system included four curing periods of 5-second duration, while the 6 seconds curing time of the plasma arc included two curing periods of 2 seconds and two periods of 1-second duration, respectively. May be the 1-second curing period of plasma arc has not been effective on bond strength. In many articles, the curing time for plasma arc system and halogen light has been designed as two mesial and distal curing periods to reduce pulpal effect of the heat produced by the curing systems since the increased heat following the light cure composite polymerization is either due to the absorbed energy during curing or due to the polymerization process,[3,7] the former being of more significance. Anyhow, the increased heat may cause pulpal damage,[18] sometimes surprisingly irreversible pulpits.[19] Therefore, increasing the curing periods from 2 to 4 can not only increase shear bond strength, but also prevent pulpal damage, for according to studies by Zac, Cohen, and Scheinin,[19] a pulp temperature of higher than 42.5°C may cause irreversible pulpal damage. In a study by Haning and Bott,[20] the use of plasma arc for 10 seconds and halogen light for 40 seconds cause 7.8°C and 5.59°C increase in the pulp temperature, respectively. Though this temperature and time lies within a range that can cause pulpal damage, this study has been carried out on class II restorations and cannot be properly compared to orthodontic brackets bonding.[20] The use of such curing periods in different areas to reduce the pulpal damage produced by heat was also confirmed by Oesterle.[7] He believed that this procedure can lead to better diffusion of heat or light energy to the base of bracket, i.e., the theory behind the present study.

Oesterle compared plasma arc and halogen light cure device. He applied 3 seconds curing periods for plasma arc and in three curing periods including 3 seconds-6 seconds (3 seconds mesial, 3 seconds distal) – 9 seconds (3 seconds mesial, 3 second distal, and 3 second occlusal) curing period with halogen light and concluded that the plasma arc with curing periods of 6 seconds and 9 seconds produces a bond strength value similar to that of the halogen light with a curing time of 40 seconds. He also concluded that increasing the curing periods at different sites reduces the pulpal effect of the plasma arc on the teeth. Yet, he did not compare his own opinion on "the effect of light energy on bracket's base" to "the effect of multiple curing periods on shear bond strength of orthodontic brackets." Mention should be made of the fact that in the present study, shear bond strength values of the four groups above were higher than the least standard value needed in orthodontics, this value being 6-8 Mpa.[9,21]

In the present study, to ensure complete curing of composite under the orthodontic brackets, a wedging of 45° was done on the gingival side of acrylic resin to simulate *in vivo* conditions. In the study by Yussof *et al.*,[10] the effect of the angle of the curing tip on the bond strength of orthodontic brackets was studied and the composites were cured at three different angles of 0°, 45°, and 90° from a 3mm distance. The study showed that there was no statistically significant difference between bond strength of orthodontic brackets and light cure tip angulations of 0°, 45°, and 90°. Of course, in this study, changing the position of the light cure tip from one area to another was considered and just the curing tip angle in one site was investigated. In the present study, yet, to standardize the experiment conditions, just the curing at 45° was used with light cure curing.

In this study, the shear bond strength of orthodontic brackets was evaluated via Instron device after 120 hours of maintenance in distilled water, since, according to Hajrassie and Kheir[22] and McCourt *et al.*,[23] the shear bond strength value obtained after 24 hours of bonding of the brackets was not significantly different from that obtained after 30 days. Seemingly, more studies should be carried out on the effect of increasing curing periods at different sites of the oral cavity on the bond strength of orthodontic brackets bonded with light cure systems.

CONCLUSION

Regarding the limitations of this *in vitro* study, since there was no statistically significant difference between shear bond strength of orthodontic brackets bonded to teeth with halogen light and that of brackets bonded with plasma arc, the use of plasma arc system is preferable due to shorter curing time of bonding. On the other hand, increasing the curing periods from 2 to 4 (with equal times) led to a significant increase in bond strength with halogen light system. Hence, four-directional curing is advisable for this group.

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