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EFFECT OF HIGH-INTENSITY LED UNITS AT REDUCED CURING TIME ON IN VITRO BOND STRENGTH OF ORTHODONTIC BRACKETS

Aim: *To compare the shear bond strength of stainless steel brackets obtained by 3 high-intensive light-emitting diode (LED) units with conventional halogen polymerization.* ***Methods:*** *A standard light-curing adhesive paste was used to bond brackets using different lamps and curing times. Eighty permanent bovine incisors were obtained and randomly divided into 4 groups. The first group was bonded using a high-output halogen lamp for 20 seconds, which served as a positive control. The other 3 groups were bonded with high-intensive LED curing devices for 10 seconds. After 30 minutes, a universal testing machine was used to apply an occlusal shear force directly to the enamel-bracket interface at a speed of 0.5 mm/minute. The groups were compared using Kruskal-Wallis test.* ***Results:*** *Mean results and standard deviations for the groups were: group 1 = 11.22 MPa (1.68), group 2 = 10.35 MPa (1.92), group 3 = 11.19 MPa (2.62), and group 4 = 11.82 MPa (2.09). No significant difference was observed in the bond strengths of the 4 groups evaluated (*P *= .176).* ***Conclusions:*** *Under the conditions of the present study, the high-intensity LED units with reduced light-curing time bonded brackets to etched tooth enamel as well as the halogen-based light-curing units.* World J Orthod 2008;9:203–208.

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Orthodontics has benefited from the introduction of the light-cured adhesive systems for bonding orthodontic brackets, which provide ample time to accurately position the bracket on the tooth before polymerization.[1,2] The disadvantage is the time it takes to expose each bonded bracket to the light to ensure adequate polymerization to sustain the orthodontic forces applied to the tooth at initial ligation of the archwires.[3,4]

The most common method of delivering blue light is halogen-based light-curing units (LCUs),[5] which have bulbs that produce light when electric energy heats a tungsten filament.[6] This light conversion is inefficient because the light power output is less than 1% of the consumed electrical power, limiting its lifetime to 40 to 100 hours due to bulb degradation by the heat generated.[5,7–10] Bulbs should be replaced every 6

Table 1 Light-curing units investigated and polymerization times

Light	Type	Time (s)	Tip size (mm)	Power density (mmW/cm$^{2)}$
Ortholux XT (control)	Halogen	20	8	640
Ortholux LED	LED	10	8	980
Radii LED	LED	10	8	1,400
Bluephase LED	LED	10	8	1,450

months.[11] This results in a reduction of the LCU's curing effectiveness over time, light-activated dental materials with poorer physical properties, and an increased risk of premature failure of restorations or bonded brackets.[7]

Mills[5,12] proposed light-emitting diode (LED) units as a polymerization source for light-cured composite resins because breakthroughs in LED semiconductor technology led to higher luminous intensities.[11] They have a potential lifetime of over 10,000 hours[13,14] and can be subjected to mechanical shock and vibration with very low failure rates.[3,5] No significant differences in physical properties such as compressive strength, flexural strength, or modulus of elasticity were found between composites polymerized with halogen units and those cured with LED units.[15]

The first generation of orthodontic LED curing units had lower light intensities than halogen-based devices. Manufacturers of LED units have recommended light-curing times of 20 to 40 seconds for polymerizing composite restorative materials 2 mm thick.[11] Previous investigations have not recommended reducing the exposure time with LED light-curing units to bond brackets, indicating that a 20-second polymerization time is ideal.[11,16]

Manufacturers have recently turned their attention to the development of LED light sources with irradiance values over 1,000 mW/cm^2 to improve curing effectiveness. In this in vitro study, modern high-intensive LED curing units from 3 manufacturers were tested under the same conditions at 10 seconds of polymerization to evaluate their ability to bond orthodontic stainless steel brackets at reduced time. The null hypothesis was that there would be no difference in the shear bond strength among groups regardless of whether a halogen-based or LED light-curing unit was used for a reduced time.

METHODS AND MATERIALS

Materials

Eighty freshly extracted bovine permanent mandibular incisors were collected and stored in a solution of 0.1% (wt/vol) thymol at room temperature. Previous studies concluded that bovine enamel can be used as a substitute for human samples in adhesion tests because of its similarity in physical properties, composition, and bond strength.[17,18] The criteria for tooth selection included intact buccal enamel, no subjection to pretreatment chemical agents, and no cracks or caries. The teeth were cleansed of soft tissue, and the crowns were separated from the roots and mounted in plastic rings with acrylic resin. The crowns were oriented so that the labial enamel surface would be parallel to the force during the shear strength test.

Bonding procedure

Stainless steel maxillary central incisor brackets (Dental Morelli, São Paulo, Brazil) were used in this study. The average bracket base surface area was 12.02 mm^2. The buccal enamel surface of each tooth was dried and etched for 30 seconds. The specimens were then rinsed with sterile water for 40 seconds and dried with oil-free air for 20 seconds. In all cases, the frosty white appearance of etched enamel was noticed. A layer of Transbond XT primer (3M Unitek, Monrovia, California, USA) was applied on the tooth. Transbond XT paste was applied to the base of bracket.

All materials were mixed and applied according to the manufacturers' instructions by a single operator (N.P.), and the brackets were bonded with 1 of 4 visible light-curing units (Table 1). Group 1 was cured with Ortholux XT (3M Unitek), a halogen-based visible light-curing unit, for 20 seconds, which served as a positive control. The other 3 groups were bonded with high-intensity LED visible light-curing units for 10 seconds: group 2 with the Ortholux LED (3M Unitek), group 3 with the Radii LED (Southern Dental Industries, Victoria, Australia), and group 4 with bluephase LED curing unit (Ivoclar Vivadent, Schaan, Liechtenstein).

The distance of the curing tip was standardized at 2 mm by placing a piece of wire adjacent to the bracket base. The light source was placed on the mesial side of the bracket/tooth interface for half the total cure time and on the distal side for the remaining time. The power densities were checked by a handheld radiometer (Demetron 100, Demetron Research, Dannbury, Connecticut, USA) to ensure that they were operating properly after each bracket was bonded and to certify the manufacturers' data.

Testing procedure

The bracket-tooth interface for each specimen was tested after 30 minutes in shear with a sharp, chisel-shaped rod attached to a universal testing machine (EMIC MFdI 500, Paraná, Brazil) at a crosshead speed of 0.5 mm/minute until bracket failure. The edge of the chisel was carefully positioned at the interface of the tooth and bracket. The force in newtons was recorded for each specimen and divided by the surface area of the bracket pad to obtain the shear stress value in megapascals (MPa).

After debonding, the teeth and brackets were examined under 10× magnification (Olympus Optical, Hamburg, Germany) to evaluate the amount of resin remaining on the tooth. The adhesive remnant index (ARI)[19] was used to describe the quantity of resin remaining on the tooth surfaces. The ARI score has a range between 0 and 3 as follows: 0 indicates that no composite remained on the enamel; 1, less than 50% of composite remained on the tooth surface; 2, more than 50% of the composite remained on the tooth; and 3, 100% of the composite remained on the tooth.

Statistical analysis

Descriptive statistics, including the mean, standard deviation, and minimum and maximum values, were calculated for each group tested. The data of bond strength were tested for normality with the Shapiro-Wilk method. The Kruskal-Wallis test was used to determine whether significant differences were present in the bond strengths among the 4 groups. The chi-square test was used to evaluate differences in the ARI scores among groups. All statistical analyses were performed with the software Prism 4.0 (GraphPad Software, San Diego, California, USA) at a 5% level of significance.

RESULTS

The descriptive statistics comparing the shear bond strength of orthodontic brackets bonded to teeth with a halogen-based or a LED light-curing unit are shown in Table 2. The Kruskal-Wallis test did not show significant differences (P = .176) among the groups evaluated. Group 4 (bluephase LED) had a mean shear bond strength of 11.82 ± 2.09

Table 2 Results of Kruskal-Wallis test comparing shear bond strengths (MPa) of experimental groups

	n	Mean*	SD	Range
Ortholux XT (control)	20	11.22	1.68	8.90–14.68
Ortholux LED	20	10.35	1.92	7.08–14.20
Radii LED	20	11.19	2.63	8.10–17.30
Bluephase LED	20	11.82	2.09	9.12–15.63

*P = .176.

Table 3 Frequency distribution and results of chi-square analysis of the ARI of the 4 groups tested

		ARI scores* #			
	n	0	1	2	3
Ortholux XT (control)	20	9	6	3	2
Ortholux LED	20	1	2	4	13
Radii LED	20	1	1	2	16
Bluephase LED	20	0	2	3	15

* 0, no adhesive remaining on tooth; 1, less than half of enamel bonding site covered with adhesive; 2, more than half of enamel bonding site covered with adhesive; 3, enamel bonding site covered entirely with adhesive.
χ^2 = 36.08; P =.0001. #, statistical analysis of the ARI scores.

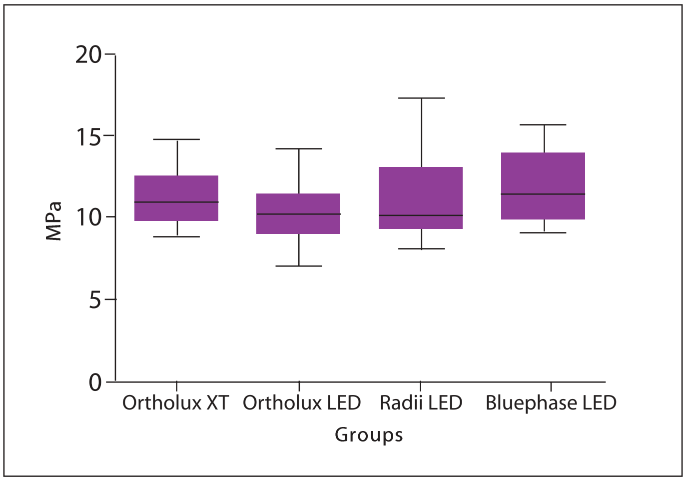

Fig 1 Box plots of the shear bond strengths (MPa) of the experimental groups.

MPa, while the control group with halogen-based light-curing unit had a mean of 11.22 ± 1.68 MPa (Fig 1).

Table 3 lists the ARI scores for the 4 groups tested. The results of chi-square comparisons for the ARI indicated significant differences (P = .0001) between the group that was bonded with a halogen-based light-curing unit and the others. With the use of LED curing units, there was a higher frequency of ARI scores of 2 and 3, which indicated more composite remained on the teeth.

DISCUSSION

The null hypotesis was not rejected. The results of the present study indicated that the shear bond strength of the orthodontic brackets bonded when using the high-power LED light-curing units for 10 seconds was not significantly different from that obtained when brackets were cured with the standard halogen light-curing unit for 20 seconds. Debonding occurred in 30 minutes after bonding orthodontic brackets to teeth in order to simulate the clinical situation.

Light output, composite composition, and exposure time are the main factors that affect polymerization.[20] Some years ago, there was a concern that commercially available LED light-curing units could not match the power output of the halogen-based lights. The manufacturers claim that the new high-intensity LED units combine all the advantages of their predecessors, maximizing bond strength with a considerable reduction in exposure time. In orthodontics, they are useful to avoid inadequate polymerization of adhesive composites and resultant unpolymerized monomers that could cause bracket failure.

Previous studies found significant differences among lights and curing times when comparing LED units with halogen-based devices.[10,11,16] As expected, higher bond strengths were obtained with longer curing times. Swanson et al[11] compared shear bond strengths of brackets bonded with LED curing units for 40, 20, and 10 seconds. Although they found adequate bond strengths with even a 10-second cure, they recommended longer periods of polymerization. Usümez et al[10] suggested that 20 seconds of LED exposure might generate shear bond strengths comparable to those obtained with halogen-based units for 40 seconds. However, they also reported significantly decreased values with 10-second LED curing. While evaluating the influence of light-tip distance in bond strength with different light sources, Cacciafesta et al[21] found lower shear bond strengths when using the LED light at 3 and 6 mm from the bracket base, but the curing time was 6 seconds, considered inadequate by previous investigations and some manufacturers.[10,11,16,22]

The high-powered LED curing units can be considered a second generation of LED light sources, a result of improving semiconductor technology by increasing the power densities and reducing the number of LEDs in the light tips. The present study indicates that the new intensive LED curing units may improve the light effectiveness and reduce the time necessary to bond orthodontic brackets, as suggested by manufacturers. Actually, there is not a universally accepted minimum clinical bond strength. However, the bond strength required to withstand normal orthodontic forces is thought to be between 8 and 9 MPa.[23] In this study, bracket failure occurred between 10.35 and 11.32 MPa. In fact, high values of bond strength might not be the most desirable characteristic, because brackets must be removed at the end of treatment and clinical problems with enamel cracks could occur during debonding in cases of excessive bond strength.[24] These results are in agreement with other studies that suggest adequate bond strengths can be achieved with LED curing lights.[4,6,10,11,15,25]

The evaluation of the ARI scores indicated significant difference in bond-failure site among the 4 experimental groups. These results showed that LED units left more adhesive on the enamel than when a halogen-based light-curing unit was used. This can be advantageous for clinicians because bond failure at the bracket-adhesive interface or within the adhesive is more desirable than at the adhesive-enamel interface, in order to avoid enamel fracture at the time of debonding.[23,26]

New high-powered LED curing units are promising devices. From a clinical standpoint, the use of LEDs can be desirable because they save chair time, have no need for filters, and have a higher input-to-output efficiency. This has allowed the development of smaller and lighter cordless units with rechargeable batteries. However, this was an in vitro study and care should be taken in interpreting the results. In order to recommend large-scale use of this product, more studies are required, particularly in vivo studies and clinical trials.

CONCLUSIONS

Under the conditions of this investigation, the results suggest no difference in bond strength between high-intensity LEDs and halogen-based light-curing units.

The amount of adhesive on enamel after debonding was significantly higher when using high-intensity LED units than halogen-based light.

The present results indicate that the use of high-intensity LED curing units is potentially adequate for orthodontic bonding needs, even if the exposure time is reduced to 10 seconds.

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