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Effects of Light-Emitting Diode and Halogen Light Curing Techniques on Ceramic Brackets Bonded to Porcelain Surfaces

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ABSTRACT

The objectives of this study were to test the efficiency of LED curing devices in bonding ceramic brackets to porcelain surfaces and to compare the effects of LED and halogen curing techniques on shear bond strength of ceramic brackets. A total of 20 glazed porcelain facets were randomly divided into two groups of 10. Porcelain surfaces were etched with 9.6% hydrofluoric acid for 2 minutes, and silane was applied on the etched porcelain surface. Ceramic brackets were bonded with an LC composite resin cured with soft start mode LED and a halogen light. Bond strengths, as determined in the shear mode, were higher in the LED group ($P < .001$). LED curing units with the soft start polymerization mode were more effective than halogen curing units in bonding ceramic brackets on porcelain surfaces. The type of curing light must be considered as an important factor affecting bond strength of ceramic brackets on porcelain surfaces.

KEY WORDS: Ceramic, LED, Porcelain, Shear bond strength, Silane, Soft start polymerization.

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INTRODUCTION Return to TOC

An increase in the number of adults seeking orthodontic treatment has given rise to new problems for orthodontists. One of these problems is the bonding of orthodontic brackets on teeth restored with resin, porcelain crowns, or amalgam fillings.

Many studies have investigated the bond strengths of metallic,[1–5] ceramic,[6–9] and composite[10] orthodontic brackets bonded to porcelain surfaces. Because the conventional acid-etch technique is ineffective on porcelain surfaces, four types of surface-conditioning techniques were used in these studies:

- Roughening the porcelain surface with a diamond drill or sandpaper discs;[2,4]
- Sandblasting with aluminum oxide particles;[7,8]
- Chemical preparation with hydrofluoric acid;[7–9,11]

- Use of silanes (gamma-methacryloxypropyl-trimethoxy silane) that provide a chemical link between porcelain and composite resin and increase the wettability of the porcelain surface.[1–3,8,9,11–14]

The effects of these conditioning methods and various adhesives have been compared in the literature.[1–3,8,9,11–14] However, the type of curing light has not been considered as a factor affecting bond strength of ceramic brackets on porcelain surfaces. Specifically, aggressively marketed light-emitting diode (LED) curing devices have not been tested for bonding ceramic brackets to porcelain surfaces.

Therefore, the aims of this study were

- To test the efficiency of LED curing devices in bonding ceramic brackets to porcelain surfaces,
- To compare the effects of LED and halogen curing techniques on the shear bond strength of ceramic brackets bonded to porcelain surfaces.

MATERIALS AND METHODS Return to TOC

A total of 20 glazed porcelain facets were produced by duplication of the labial surface of a maxillary first premolar. The facets were made from Vita porcelain (Vita, Bad Sackingen, Germany) by the condensing technique and baked under vacuum at 940°C. Each porcelain was individually embedded in autopolymerizing acrylic resin (Meliodent, Herause Kulzer, Hanau, Germany). The mounted specimens were randomly divided into two groups of 10.

The porcelain surfaces were etched with 9.6% hydrofluoric acid (Pulpdent, Watertown, Mass.) for 2 minutes, rinsed with a water/spray combination for 30 seconds, and dried before application of silane. Silane primer (Ormco Porcelain Primer, Ormco, Glendora, Calif) was applied on the etched porcelain surface with a microbrush and allowed to dry for 5 minutes.

Spirit ceramic brackets (Ormco) were bonded with an LC composite resin Light Bond (Reliance Orthodontic Products Inc, Itasca, Ill). A thin uniform layer of sealant was applied on the etched porcelain surface with a microbrush and cured for 20 seconds. A thin coat of sealant was also painted on the ceramic bracket base for chemical retention and cured for 10 seconds before applying the paste. Using a syringe tip, the paste was applied to the bracket base. Then, the bracket was positioned on the porcelain tab and pressed lightly. Excess adhesive was removed with a sharp scaler.

Group 1 specimens were cured with soft start mode (low-intensity lights followed by a final exposure with high-intensity light) LED (MiniLED™, Satelec, Merignac, France) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surfaces of the brackets Group 2 specimens were cured with halogen light (Heliolux DLX, Vivadent ETS, Schaan, Liechtenstein) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surfaces of the brackets).

All specimens were stored in distilled water at 37°C for 24 hours and thermocycled for 500 cycles between 5°C and 55°C, using a dwell time of 30 seconds. Each specimen was loaded into a universal testing machine (Lloyd; Fareham, Hants, UK) using Nexijen software for testing, with the long axis of the specimen perpendicular to the direction of the applied force. The standard knife-edge was positioned to make contact with the bonded specimen. Bond strength was determined in the shear mode at a crosshead speed of 0.5 mm/ min until fracture occurred. Values of failure loads (N) were recorded and converted into megapascals (MPa) by dividing the failure load (N) by the surface area of the bracket base (10.60 mm^2).

Statistical analysis

Descriptive statistics, including the mean, median, standard deviation, and quartiles, were calculated for each of the groups tested. One-way analysis of variance (ANOVA) was used to compare the shear bond strengths of the groups. Significance for all statistical tests was predetermined at $P < .05$. All statistical analysis were performed with SPSS version 11.0.0 (SPSS Inc, Chicago, Ill).

RESULTS Return to TOC

The descriptive statistics on the shear bond strength (MPa) for the groups are presented as boxplots in Figure 1. ANOVA indicated a significant difference between groups ($P < .001$) (Table 1) with higher shear bond strengths measured in the LED group ($P < .001$).

DISCUSSION Return to TOC

With the increasing number of adult patients, orthodontists often face the challenge of bonding brackets to porcelain crowns. Because glazed porcelain surfaces are not amenable to resin penetration for orthodontic bonding,[12] mechanical or chemical pretreatment of the surface is essential for successful direct bonding to porcelain. Previous research has shown that chemical conditioning with hydrofluoric acid[7–9,11] or silanes[1–3,8,9,11–14] successfully increases the adhesion of the composite resin to the porcelain surfaces, but mechanical roughening methods are reported to provoke the initiation of cracks within the porcelain.[8,15,16] In this study, hydrofluoric acid etching and silanes were used together, which has been proved to produce higher bond strengths than the other surface-treatment methods.[8,10]

Excessively high bond strengths obtained in previous research may not correlate well with clinical success. The oral cavity is a complex environment with variations in temperature, stresses, humidity, acidity, and plaque.[7] Although it is impossible to reproduce a laboratory condition, which fully represents the oral environment, storage conditions and variations in temperature must at least be similar. Therefore, all specimens were stored and thermocycled as recommended for quality testing of adhesive materials by the International Organization for Standardization in 1993.[17]

It has been reported that thermal cycling weakens the bond to porcelain surfaces to an unsatisfactory level.[18,19] If thermocycling is not performed, excessively higher bond strengths to porcelain are obtained. The relatively low bond strengths obtained in this study can be explained by the effect of thermocycling.

The minimal bond strength to withstand orthodontic forces is 6–8 MPa.[20] On the other hand, Thurmond et al[21] reported that bond strengths higher than 13 MPa resulted cohesive fractures of the porcelain surface. Our results revealed that surface conditioning with hydrofluoric acid for 2 minutes followed by silane application provided sufficient bond strengths in both groups. However, the higher bond strengths obtained with LED curing devices are noteworthy. In previous research, light-cured orthodontic adhesives were cured almost exclusively with light emitted from a halogen light. However, halogen technology has several shortcomings.[22] Only 1% of the total energy input is converted into light, with the remained energy generated as heat. The short life of halogen bulbs and the noisy cooling fan are other disadvantages.

Recently, high-power LED light sources (≧1000 mW/cm^2) were introduced to the dental market. The rationale for a high-power light source is that more photons are available for absorption by the photosensitizers,[23] and with more photons, more camphorquinone molecules are raised to the excited state, react with the amine, and form free radicals for polymerization.[24]

Previous research has shown that LED curing units are as effective as halogen-based curing units in bonding metal orthodontic brackets to tooth enamel.[25–28] However, this higher light intensity produces higher contraction strains during resin polymerization and contraction stresses may contribute to insufficient clinical shear bond strength.[29–32] To overcome this problem, the use of low-intensity lights followed by a final exposure with high-intensity light was introduced and termed soft start polymerization.

Studies have demonstrated that soft start polymerization techniques significantly reduce polymerization strains and improve material properties.[29,30,33] Besides, soft start polymerization mode of LED devices has been proved to produce higher bond strengths than halogen devices.[34] Our results also demonstrated that soft start LED polymerization provided higher bond strengths for ceramic brackets on porcelain surfaces.

CONCLUSIONS Return to TOC

- Surface treatment with hydrofluoric acid and silane-coupling agent provided sufficient bond strengths to withstand orthodontic forces.
- LED curing devices with soft start polymerization mode are more effective than halogen curing units in bonding ceramic brackets to porcelain surfaces.
- The type of curing light must be considered as an important factor affecting bond strength of ceramic brackets on porcelain surfaces.

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TABLE 1. The Descriptive Statistics and the Results of the Analysis of Variance (ANOVA) Comparing the Shear Bond Strengths of the Groups[a]

Group 1 (LED)				Group 2 (Halogen)				
		95% Confidence Interval for Mean				95% Confidence Interval for Mean		
Mean	SD	Lower Bound	Upper Bound	Mean	SD	Lower Bound	Upper Bound	Significance
11.38	1.65	10.21	12.56	7.59	1.42	6.57	8.61	0.000

[a] LED indicates light-emitting diode.

FIGURES Return to TOC

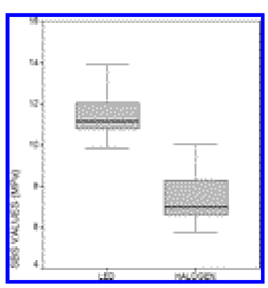

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FIGURE 1. Shear bond strengths (MPa) of the groups. Results are presented as boxplots. Horizontal line in middle of each boxplot shows median value; horizontal lines in box give 25% and 75% quartiles; lines outside box give 5% and 95% quartiles

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