Porcelain Veneer Bonding to Enamel with Plasma-arc Light Resin Curing

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The resin bond strength of plasma-arc curing in restorative dentistry was investigated in comparison to halogen-light curing with respect to two kinds of thickness, shade and opacity of porcelain laminate veneers. The bond strength of the light-cured resin was evaluated by shear tests and SEM observations of the fracture surfaces, and the results were interpreted in terms of the degree of resin polymerization. It was found that plasma-arc curing for 6 s was sufficient to obtain bond strengths similar to those of specimens polymerized with halogen light for 40 s, whereas the plasma-arc curing time needed to be doubled to 12 s in order to achieve similar failure patterns for a darker-shade porcelain of 2 mm thickness. The bond strength achieved by plasma-arc curing was found to be relatively unaffected by the shade or opacity of porcelain.

Key words: Porcelain laminate veneer, resin curing, plasma-arc light

INTRODUCTION

High-intensity chair-side curing units have recently become commercially available. Among the new units, plasma-arc lights with an energy peak at wavelengths between 460 and 480 nm are expected to allow efficient polymerization of most types of composite resin in a shorter time compared to commonly used halogen curing units.

Light-cured or dual-cured resin cements are used for cementing porcelain laminate veneers. As laminate veneer restorations do not offer mechanical retention themselves, the adhesive strength of the cement should be adequate to hold the restoration in place when initially positioned. Although the bond strength is considered to be reliably high using conventional procedures, the thickness, shade and opacity of the porcelain may negatively influence the degree of polymerization and the mechanical properties of resin cements.

Higher-intensity curing light may reduce the effect of these porcelain properties, thereby allowing consistently high bond strengths to be achieved for all types of porcelain laminate veneers.

In this study, the characteristics of resin cement were analyzed over a range of porcelain thicknesses, shades, and opacities, and for two curing light sources, plasma-arc and halogen lights, in order to determine the optimal conditions for achieving high bond strength between porcelain and enamel.
MATERIALS AND METHODS

1. Sample preparation
Bovine mandibular incisors, frozen immediately after extraction and with the vestibular face ground with a diamond trimmer without exposing the dentin, were embedded in epoxy resin. The flat surface of the trimmed enamel was then polished using 600-grit carborundum paper under running water.

Two types of porcelain were used in this study; Cerec II Vitablock Mark II (VITA Zahnfabrik H. Rauter GmbH & Co., Bad Sakingen, Germany) of shade A1 or A3.5, and Clearpearl porcelain (Kuraray Co., Okayama, Japan) of shade A1. Cerec II porcelain blocks of 8×8 mm were cut into two slices 1 and 2 mm thick. Clearpearl porcelain blocks, in both opaque and translucent forms, were routinely produced as 1 mm-thick plates, ground to 8×8 mm, and polished with 600-grit carborundum paper.

2. Adherent surface treatment
The adherent porcelain surfaces were treated with a mixed solution of 13% hydrofluoric acid and 15% sulfuric acid (Uni Clean, Shofu Co., Tokyo, Japan) for 60 s, washed in an ultrasonic bath of distilled water for 60 s, air-dried, treated with 37% phosphoric acid (K-etchant gel, Kuraray Co., Okayama, Japan) for 30 s, washed in an ultrasonic bath of distilled water for 60 s, and then air-dried. Clearfil Photo Bond and Porcelain Activator (Kuraray Co., Okayama, Japan) were mixed and applied to these surfaces.

The adherent enamel surfaces were treated with 37% phosphoric acid for 30 s, rinsed with water, air-dried, treated with Clearfil Photo Bond, and subsequently air-dried.
3. Adhesion methodology and shear test
Masking tape (Scotch mending tape, 3M) with a 6-mm hole was applied to the adherent enamel surface in order to ensure that equal volumes of resin cement were applied in each run. Clearpearl resin cement (LC universal, Kuraray Co., Okayama, Japan) was applied into the hole in the masking tape, and the porcelain was then pressed onto the cement under a 100-g weight. The tip of the light-curing unit was then applied to the porcelain from the top (Fig. 1). The plasma-arc light (Apollo 95E, Dental Medical Diagnostic Systems Inc., California, USA) was applied for 6 or 12 s, and the halogen light (Clearlight, Kuraray, Okayama, Japan) was applied for 40 s.

After polymerization, the specimens were maintained at room temperature for 5 min and then mounted in the jig of a universal testing machine (Autograph AGS-10kND, Shimadzu Co., Kyoto, Japan). The shear bond strength was measured at a cross-head speed of 2 mm/min, with the load parallel to the adhesive surface applied at the porcelain (Fig. 2). Five specimens were prepared for each group.

4. Statistical Analysis
Student’s t-test with Bonferroni’s correction was performed to compare the bond strengths. The significance level was set at $p=0.05/12=0.004$ for the results of the graph in Fig. 3 and Table 1, and at $p=0.05/4=0.0125$ for the results of the graph in Fig. 4 and Table 2.

5. Observation of fractured surfaces
After the shear tests, the specimens were spatter-coated with gold and the fracture

![Fig. 3 Shear bond strength of resin between porcelain and enamel for various porcelain types and two light sources. Error bars indicate standard deviation. There were no significant differences in the strength between any two experimental groups at the $p=0.004$ level.](image-url)
### Table 1 Statistical results of Student's t-test with Bonferroni's correction for the effects of porcelain shade and thickness on shear bond strength (p-value)

<table>
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Significant level of $p=0.05/12=0.004$

Fig. 4 Shear bond strength of resin between porcelain for the two light sources according to the opacity of the porcelain laminate veneer (shade: A1; thickness: 1 mm). Error bars indicate standard deviation. There were no significant differences in the strength between any two experimental groups at the $p=0.0125$ level.
Table 2 Statistical results of Student's t-test with Bonferroni's correction for the effects of porcelain opacity on shear bond strength (p-value)

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Significant level of $p=0.05/4=0.0125$

Table 3 Fracture patterns after shear strength test

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<th>Rp</th>
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<td>3</td>
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</table>

Re: Adhesive failure between resin cement and enamel
R: Cohesive failure of resin cement
Rp: Adhesive failure between resin cement and porcelain
M: Mixed failure

RESULTS

1. Effect of porcelain shade and thickness
The shear bond strength of the cement between the Cerec II porcelain and enamel is shown in Fig. 3 for various porcelain shades and thicknesses and the two light-curing sources. Statistical results are summarized in Table 1. No significant differences in bond strength were found between the two types of light-curing units, porcelain thickness or shade.

2. Effect of porcelain opacity
The effect of opacity of the 1 mm-thick Clearpearl porcelain of shade A1 on shear strength is shown in Fig. 4 for the two curing sources. Statistical results are summarized in Table 2. No significant differences were found among groups.

3. Fractured surface observation
The characteristic surface fracture patterns of the cement after the shear strength tests are shown in Table 3. Of the total 20 specimens, interfacial fractures between the resin and enamel were observed in 3 cases, 5 specimens exhibited cohesive resin failure, and 12 specimens formed mixed failures. No clear relationship between bond appearance was analyzed using a scanning electron microscope (SEM; DS-720, Topcon, Tokyo, Japan).
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Fig. 5 SEM images of fracture surfaces.

strength and fracture pattern was observed in these specimens.

SEM observations revealed a large amount of resin remaining on the enamel surface (Fig. 5, left) of specimens with low bond strength, whereas for specimens with high bond strength, the fracture occurred near the interfacial zone, leaving only a small amount of bonding resin on the enamel surface (Fig. 5, right).

DISCUSSION

This investigation revealed that the bond strengths of restorations using light-shaded porcelain (A1) or darker-shaded (A3.5) were consistent up to a laminate thickness of 2 mm, irrespective of curing light source (6 s plasma arc or 40 s halogen). However, the SEM analysis revealed a large amount of resin remaining on the enamel surface of relatively low-strength samples after the shear strength test. This might be due to insufficient polymerization of the resin cement. Insufficient energy input as a result of light energy absorption by the porcelain results in inadequate polymerization of the resin, which will become evident at the deepest level of polymerization or at the adhesive interface.

Opaque porcelain is often used in the first layers of porcelain laminate veneer restoration in order to conceal discoloration and improve esthetics. In this study, although there was no clear relationship between bond strength and fracture pattern, most specimens with low bond strength exhibited cohesive failure of the resin cement, with large amounts of resin remaining on the enamel surface (Fig. 5). As mentioned above, this is thought to be due to inadequate polymerization.

In all light curing processes, the opaque nature of the porcelain laminate will reflect and refract the light, decreasing the total energy that reaches the adhesive interface. Plasma-arc light has been shown to heat up the adhesive interface much more rapidly than halogen light, with a corresponding acceleration of polymerization. This is why the bond strength achieved by plasma-arc curing is similar to that
by halogen light. However, the relationship between energy input, temperature and polymerization activation remains to be clarified.

The selection of the porcelain pre-treatment method used in this study was based on the good bond strength results obtained in previous research. Hydrofluoric acid and a ultra-sonic bath are used to expose calcium and potassium ions, and phosphoric acid is used to oxidize the surface. Based on the results of this study, we can conclude that for the adhesion of porcelain laminate veneer to enamel using a light-cured resin composite, plasma-arc curing is capable of achieving bond strengths similar to those obtained by halogen-light curing, with shorter curing times. Particularly for laminate veneer restorations, when a number of teeth are commonly treated in a single session, the shorter polymerization time required by plasma-arc curing will be of significant importance in a clinical setting. As demonstrated by the results obtained in this study, the curing time should be changed according to the shade and thickness of the restoration laminate.

**CONCLUSIONS**

1) The curing of resin cement through 1-mm porcelain by the application of plasma-arc light for 6 s was found to be sufficient to obtain an enamel bond similar to that for specimens cured by halogen-light for 40 s for a range of opacities and shades.

2) Plasma-arc light curing for 6 s was found to be insufficient to adequately polymerize resin cement through 2-mm porcelain to the same levels as by halogen-light curing for 40 s. Doubling the curing time to 12 s was sufficient to achieve similar results to that by halogen-light curing.

3) Plasma-arc light curing units are expected to become useful in a clinical setting for treatments such as laminate veneer restoration as a result of the shorter curing times.

**ACKNOWLEDGMENTS**

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**REFERENCES**


