Effects of surface conditioning on the shear bond strength of orthodontic brackets bonded to temporary polycarbonate crowns

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Introduction: An increase in the number of adults seeking orthodontic treatment has given rise to new problems for orthodontists, one of which is the need to bond orthodontic brackets to teeth restored with temporary crowns. Many prefabricated temporary crowns are composed of polycarbonates or thermoplastic polymers; bonding to these surfaces is complex because of the composition, surface integrity, and resistance of the crowns. The bond must be sufficient to resist breakage from the forces of orthodontic biomechanics and oral functions including mastication. The purpose of this study was to test, in vitro, the effect of different surface treatments on the shear bond strength of metal and ceramic orthodontic brackets bonded to temporary polycarbonate crowns.

Methods: Eighty polycarbonate crowns for the maxillary right central incisor were evenly divided into 4 groups, and the facial surfaces were subjected to one of the following conditions: group A (control): no treatment; group B: the surface was sandblasted with 50 μm aluminum oxide particles; group C: the glazed surface was removed with a diamond bur; and group D: the surface was etched with 9.6% hydrofluoric acid. Precoated Victory metal brackets (3M Unitek, Monrovia, Calif) were bonded to the facial surface of half (n = 10) of the polycarbonate crowns in each group, and precoated Clarity ceramic brackets (3M Unitek) were bonded to the facial surface of the other half (n = 10). Each was debonded with a shear load in a universal testing machine at a crosshead speed of 0.254 mm per minute, and the adhesive remnant index (ARI) was used to analyze the sites of bond failure. Analysis of variance (ANOVA), post-hoc t test with the Bonferroni adjustment, Student t test, and chi-square test with the Yates correction were used for statistical analysis.

Results: There was a significant difference between group B (sandblasting) and all other ceramic and metal groups. In the metal groups, there was a slight difference between group C (diamond bur) and group A (control). According to the ARI, sandblasting was the only surface treatment to significantly affect the adhesion of metal and ceramic brackets to polycarbonate crowns. There was no statistically significant difference between the metal and ceramic brackets in group B (sandblasting). There was a statistically significant difference between metal and ceramic brackets in each group, with the exception of group C (diamond bur), which was just below statistical significance. Conclusions: Metal and ceramic orthodontic brackets bonded to temporary polycarbonate crowns will most likely not withstand the forces of orthodontic biomechanics. However, sandblasting polycarbonate crowns consistently increased the shear bond strength of metal and ceramic brackets. A diamond bur effectively roughens the surface of a polycarbonate crown but with no gain in bond strength. Likewise, etching the surface of polycarbonate crowns with 9.6% hydrofluoric acid is ineffective. Ceramic brackets bonded to sandblasted polycarbonate crowns produced the highest mean shear bond strength (2.87 MPa), although this value is far below bond strengths with natural tooth surfaces. (Am J Orthod Dentofacial Orthop 2010;138:72-8)
Many prefabricated temporary crowns are composed of polycarbonates, which are a type of thermoplastic polymer. The characteristics of polycarbonates are similar to those of polymethylmethacrylate, but polycarbonate is stronger and more costly. Bonding brackets to polycarbonate crowns is complex because of the composition, surface integrity, and resistance of the crowns. Due to the composition of polycarbonate crowns, they are fairly resistant to dilute acids and do not etch well. In addition, the surface integrity depends on the finishing procedure and whether the surface is glazed.

Although there have been numerous studies on increasing bond strength of orthodontic brackets to enamel and porcelain, no research has been done on the bond strength of orthodontic brackets bonded to polycarbonate. In general, acid etching, sandblasting, and roughening the surface with a diamond bur have been investigated as methods to increase bond strength. Although conventional acid etching with 37% phosphoric acid is effective for enamel, this is ineffective for the preparation of porcelain surfaces for bonding orthodontic brackets. Strong acids such as 9.6% hydrofluoric acid are commonly used to etch porcelain and increase bond strength. The action of hydrofluoric acid is to create surface pits by preferential dissolution of the glass phase from the ceramic matrix. However, hydrofluoric acid must be used carefully, since it is extremely corrosive and can cause severe trauma to soft tissues and tooth substance.

Orthodontic brackets need to be retained either mechanically or chemically to the polycarbonate crown. The bond strength should be sufficient to resist failure from the forces of orthodontic biomechanics and oral functions including mastication. The materials and techniques used in bonding should keep the brackets bonded for the duration of treatment and not damage the crown’s surface during debonding. The purpose of this research was to examine, in vitro, the effect of different surface treatments on the shear bond strength of metal and ceramic orthodontic brackets onto temporary polycarbonate crowns.

MATERIAL AND METHODS

Polycarbonate crowns (Henry Schein, Melville, NY) for the maxillary right central incisor (n = 80) were used in this study. The facial surface of each crown was pumiced with a rubber prophylaxis cup in a low-speed electric hand piece. The surfaces were then rinsed with a steady stream of water for 20 seconds and dried with a mild continuous stream of oil-free and humidity-free compressed air. The specimens were evenly divided into 4 groups, and the facial surface was subjected to one of the following conditions: group A (control): no treatment, with the glaze maintained; group B: the surface was sandblasted with 50 μm aluminum oxide particles under 90 psi of air pressure with the nozzle held 10 mm from the surface until the surface was completely frosted; group C: the glaze was removed with a diamond bur (850-014, Axis Dental, Coppell, Tex); group D: the surface was etched with 9.6% hydrofluoric acid for 4 minutes (Pulpdent, Watertown, Mass). Specimens representative of each group were coated with a conductive layer of gold and examined with a scanning electron microscope (JSM-5600, JEOL, Tokyo, Japan).

The specimens of groups B, C, and D were rinsed again with a steady stream of water for 30 seconds and dried with oil-free and humidity-free compressed air. Three coats of the primer (Scotchprime Ceramic Primer, 3M Unitek, Monrovia, Calif) were painted onto the facial surfaces of the polycarbonate crowns in every group with a disposable brush and lightly dried with oil-free and humidity-free compressed air. Precoated Victory metal brackets (3M Unitek) were bonded to the facial surface of half (n = 10) of the polycarbonate crowns in each group, and precoated Clarity ceramic brackets (3M Unitek) were bonded to the facial surface of the other half (n = 10) in each group (Fig 1). The adhesive used for all precoated brackets was Transbond XT light-curing adhesive (3M Unitek). Each bracket was positioned with a scaler, and excess adhesive was removed from the surface. All brackets were light cured with a Blue Ray light-emitting diode lamp (American Orthodontics, Sheboygan, Wis) for 40 seconds.

A specimen fixture was designed and fabricated from aluminum. Each sample was mounted on the specimen fixture. A small portion of dental wax was placed...
inside the polycarbonate crowns to secure it to the fixture. Each sample was subjected to a shear load with a universal testing machine (model SSTM-1, United, Huntington Beach, Calif) fitted with 5000-lb and 50-lb load cells. The readings were taken from the 50-lb load cell. A knife-edged blade from the upper fixture was fitted into the groove between the outer edge of the bracket and the polycarbonate crown (Fig 2). The tests were run by using the testing machine software, DATUM 4.0 (United). The crosshead speed was set to 0.254 mm per minute. The machine recorded the results in newtons. The force per unit of area required to dislodge the bracket was then calculated and reported as the shear bond strength in megapascals (MPa). The bracket base areas for the Victory metal brackets and the Clarity ceramic brackets were 11.9 mm² and 14.6 mm², respectively.

After debonding, an optic microscope with 10-times magnification was used to examine all bonding sites and classify them according to the adhesive remnant index (ARI).28 The ARI was used to analyze the sites of bond failure between the polycarbonate crown surface, the adhesive, and the bracket base.

**Statistical analysis**

Descriptive statistics including means, standard deviations, and minimum and maximum values were calculated for every group. Analysis of variance (ANOVA) was used to determine whether there were significant differences in the shear bond strength between the groups. If there were significant differences, a post-hoc t test with the Bonferroni adjustment was used to determine which means were significantly different from each other. The Student t test was used to determine significant differences between metal and ceramic brackets. The chi-square test with the Yates correction was used to determine the statistical significance of the ARI scores. The level of significance for all statistical tests was established as P ≤ 0.05.

**RESULTS**

The mean shear bond strengths, standard deviations, and ranges of all groups are given in Table I.

ANOVA was used on the ceramic brackets bonded to the facial surface of the polycarbonate crowns in the 4 groups. Since the test produced a Fisher F value of 596.96 (P = 0.000), it was determined that there was a statistically significant difference among the groups. The post-hoc t test with the Bonferroni adjustment was performed, it was determined that a significant difference existed between group B (sandblasting) and all other ceramic groups.

ANOVA was also used on the metal brackets bonded to the crowns in the 4 groups. It was also determined that a statistically significant difference existed among the groups, since the test produced a Fisher F value of 461.484 (P = 0.000). When the post-hoc t test with the Bonferroni adjustment was performed, it was determined that a significant difference existed between group B (sandblasting) and all other metal groups, and

**Table I. Shear bond strength values measured in megapascals (MPa)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Bracket-surface treatment</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Metal-control</td>
<td>10</td>
<td>0.012</td>
<td>0.010</td>
<td>0.036-0.003</td>
</tr>
<tr>
<td></td>
<td>Ceramic-control</td>
<td>10</td>
<td>0.070</td>
<td>0.040</td>
<td>0.296-0.037</td>
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<tr>
<td>B</td>
<td>Metal-sandblasting</td>
<td>10</td>
<td>1.330</td>
<td>0.170</td>
<td>1.515-1.107</td>
</tr>
<tr>
<td></td>
<td>Ceramic-sandblasting</td>
<td>10</td>
<td>2.870</td>
<td>0.360</td>
<td>3.534-2.331</td>
</tr>
<tr>
<td>C</td>
<td>Metal-diamond bur</td>
<td>10</td>
<td>0.134</td>
<td>0.064</td>
<td>0.217-0.065</td>
</tr>
<tr>
<td></td>
<td>Ceramic-diamond bur</td>
<td>10</td>
<td>0.090</td>
<td>0.020</td>
<td>0.117-0.051</td>
</tr>
<tr>
<td>D</td>
<td>Metal-etch (HF acid)</td>
<td>10</td>
<td>0.099</td>
<td>0.030</td>
<td>0.137-0.044</td>
</tr>
<tr>
<td></td>
<td>Ceramic-etch (HF acid)</td>
<td>10</td>
<td>0.030</td>
<td>0.020</td>
<td>0.065-0.009</td>
</tr>
</tbody>
</table>

HF, Hydrofluoric.
a slight difference existed between group C (diamond bur) and group A (control).

The ARI results (Table II) showed that all groups bonded with ceramic or metal brackets scored 0, since no adhesive was left on the polycarbonate crowns, except for some specimens in group B (sandblasting) for ceramic and metal brackets. Some specimens in this group scored 1 and had less than half of the adhesive left on the crown. The chi-square test with the Yates correction was done to determine whether the ARI scores between the ceramic and metal brackets in group B (sandblasting) were statistically significant. The results showed no statistically significant difference (chi-square = 0.202 with 1 degree of freedom and \( P = 0.6531 \)) between the metal and ceramic brackets in group B.

The Student \( t \) test was used to determine whether there was a statistically significant difference between the metal and ceramic brackets in each group. There was a statistically significant difference in every group \( (P < 0.05) \), except group C (diamond bur), which was just below the level of statistical significance \( (P = 0.0526) \).

The scanning electron photomicrographs of the unconditioned and conditioned polycarbonate crown surfaces are shown in Figures 3 through 6. The group A (control, glaze maintained) surfaces had a smooth appearance. The surfaces in group D (etched with hydrofluoric acid) were virtually unchanged, with the glazed surfaces appearing to be unaltered, with a smooth appearance. Group B (sandblasting) and group C (diamond bur) had roughened surfaces.

**DISCUSSION**

Several studies have been done with surfaces roughened to increase the area available for chemical or mechanical retention to porcelain.\(^{24}\) Therefore, it is reasonable to assume that surface roughening would also increase the retention of orthodontic brackets to polycarbonate crowns. The results showed that the precoated ceramic brackets bonded to the facial surface of the polycarbonate crowns that had been roughened either with a diamond bur or by sandblasting had increased shear bond strength. However, only the sandblasting treatment had a statistically significant difference compared with the control. The precoated metal brackets showed a similar result when bonded to the polycarbonate crowns. There was an increase in shear bond strength compared with the control, when the facial surface was roughened with a bur, sandblasted, and etched with hydrofluoric acid. However, only sandblasting and roughening the facial surface with a bur resulted in a statistically significant difference in shear bond strength. Not surprisingly, hydrofluoric acid had an insignificant effect on the shear bond strength of both metal and ceramic brackets to polycarbonate crowns.

Differences between ceramic and metal brackets were observed in each group. The ceramic brackets that were bonded to polycarbonate crowns with the glaze maintained or sandblasted had higher shear bond strengths than did the metal brackets in the same group. This result might be in part due to the larger surface area of the ceramic bracket bases: 14.6 mm\(^2\) compared with 11.9 mm\(^2\). Metal brackets that were bonded to the polycarbonate crowns roughened with a diamond or etched with hydrofluoric acid had higher shear bond strength compared with the ceramic brackets in the same group. The results from the ARI also showed that sandblasting was the only surface treatment to significantly affect the adhesion of metal and ceramic brackets to polycarbonate crowns. The scanning electron microscope photomicrographs showed that etching the polycarbonate crowns with hydrofluoric acid produced minimal changes and did not appear to alter the surface. This was not a surprising result because polycarbonate is resistant to strong acids. The photomicrographs also confirmed that sandblasting and a diamond bur were effective for roughening the surfaces. Sandblasting produced a randomized roughened surface with deep pockets. The diamond bur produced a patterned roughened surface with shallow grooves. This result could explain the higher shear bond strength produced by sandblasting.

Studies have been performed to test the shear bond strength of metal and ceramic brackets to porcelain and bovine teeth, but not with polycarbonate crowns. Generally, values between 5.88 and 7.85 MPa are suggested as enough to withstand orthodontic forces.\(^{29}\)

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**Table II. Distribution of the ARI scores**

<table>
<thead>
<tr>
<th>Group</th>
<th>Bracket-surface treatment</th>
<th>n</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Metal-control</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Ceramic-control</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>Metal-sandblasting</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Ceramic-sandblasting</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>Metal-diamond bur</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Ceramic-diamond bur</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>Metal-etch (HF acid)</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Ceramic-etch (HF acid)</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*HF, Hydrofluoric.*

0. No adhesive left on the crown; 1, less than half of the adhesive left on the crown; 2, more than half of the adhesive left on the crown; 3, all adhesive left on the crown, with a distinct impression of the bracket.
The bond strengths of precoated Victory metal brackets (5.4 MPa) and precoated Clarity ceramic brackets (12.7 MPa) on bovine teeth have been reported. In our study, the shear bond strengths of all tested specimens were below the clinically acceptable level for orthodontic forces. Although all tested specimens had low shear bond strengths, sandblasting increased the shear bond strength of both metal and ceramic brackets. Ceramic brackets that were bonded to the facial surface of sandblasted polycarbonate crowns had the highest shear bond strength (2.87 MPa). Although less than ideal, in a clinical situation with an anterior polycarbonate crown, a reasonable choice would be to use the combination of sandblasting treatment and a ceramic bracket to reduce the chance of bond failure.

CONCLUSIONS

The findings of this study suggest the following.

1. Metal and ceramic orthodontic brackets bonded to temporary polycarbonate crowns cannot withstand clinically acceptable orthodontic forces.
2. Sandblasting polycarbonate crowns will consistently increase the shear bond strength of metal and ceramic brackets.

3. A diamond bur will effectively roughen the surface of a polycarbonate crown but will not result in the bond strength achieved with sandblasting.

4. Etching polycarbonate crowns with 9.6% hydrofluoric acid is completely ineffective for increasing the shear bond strength.

5. Ceramic brackets bonded to sandblasted polycarbonate crowns produced the highest shear bond strength, although below a level that is comparable with other clinically acceptable bond strengths.

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REFERENCES