Shear bond strength of orthodontic brackets bonded to various esthetic pontic materials

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Introduction: In this in-vitro study, we compared the shear bond strengths of orthodontic brackets bonded to various commonly used esthetic pontic materials. Methods: Prefabricated denture teeth (acrylic resin, Trubyte, Dentsply, York, Pa) and samples made from Integrity (bis-acryl composite resin, Dentsply Caulk, Milford, Del) and Alike (polymethylmethacrylate resin, GC America, Alsip, Ill) were used to represent the more common esthetic provisional materials. Each material group contained 30 samples; a total of 90 samples were bonded in the same fashion with APC PLUS maxillary lateral incisor brackets (3M Unitek, Monrovia, Calif). Each material group was then divided into 2 testing subgroups. One subgroup was tested for shear bond strength 24 hours after bonding, and the other subgroup was tested after bonding and storage in distilled water at 37°C for a week. Each bracket was loaded perpendicularly in a universal testing machine at a crosshead speed of 1.0 mm per minute until bonding failure. The mean shear bond strength and standard deviation were determined for each group. Analysis of variance (ANOVA, 2-factor and 1-factor) with Tukey HSD post-hoc tests, Student t tests, and Mann-Whitney U tests were used to test the main effects of pontic materials and time of loading (α = 0.05). The data were stratified, and 1-way ANOVA tests were performed with the Bonferroni adjustment (α = 0.01) to examine the effect of the pontic material on shear bond strength after either 1 day or 7 days of storage. Results: Significant differences were found based on pontic material and time (P <0.05), but there was a significant interaction (P = 0.044), making the results uninterpretable. At 1 day, the Integrity material had a significantly higher mean shear bond strength than both Alike and the denture tooth materials (P <0.001). However, at 7 days, both Integrity and Alike had significantly higher mean shear bond strengths compared with the prefabricated denture tooth (P <0.001). Conclusions: Although the use of Integrity or Alike requires an additional armamentarium, necessitating individual pontic fabrication by the dental practitioner, indications for clinical use are evident with direct applications to multi-disciplinary treatment modalities.

Direct bonding of metal orthodontic brackets to natural teeth has been an accepted technique since introduced by Newman in 1965,1 with reported in-vitro bond-strength values from 6 to 8 MPa for composite resin cements.2 The strength and dependability of this bond are important to ensure effective and efficient treatment with fixed appliances.3,4 According to Zachrisson,4 a low bond-failure rate should be a high priority, since replacing loose brackets is inefficient, time-consuming, and costly. For patients undergoing orthodontic treatment involving management of anterior spacing associated with a missing tooth, maintenance of the edentulous space with an esthetic pontic is often required.5–8 Tooth loss can be a result of periodontal disease, extractions, trauma, or congenital causes. Anterior spacing is a major reason that adults seek esthetic orthodontic treatment, and provisional esthetic pontics are often required for space maintenance and desired esthetics.5,9

Secure bonding of an orthodontic bracket to an esthetic pontic during treatment depends on the properties of both the adhesive and the pontic material. As stated by Chay et al.,10 the “shear-peel bond strength of orthodontic brackets to provisional materials depends on material, surface treatment, and time.” Although various materials have been recommended for this purpose, clinicians now typically use a bracketed prefabricated plastic denture tooth (eg, interpenetrating polymer network acrylic, Trubyte, Dentsply, York, Pa), tied to the...
archwire for space maintenance. However, other esthetic materials such as bis-acryl composite resin (eg, Integrity, Dentsply Caulk, Milford, Del) and polymethylmethacrylate acrylic resin (eg, Alike, GC America, Alsip, Ill) are also used.

Few studies have been conducted on the bond strength of orthodontic brackets to provisional restorative materials. The objective of this in-vitro study was to evaluate the shear bond strength of an orthodontic bracket bonded to these commonly used esthetic pontic materials. The null hypothesis was that there is no difference in shear bond strength among the various pontic materials (Trubyte, Alike, Integrity) at either 1 or 7 days.

MATERIAL AND METHODS

Prefabricated denture teeth (interpenetrating polymer network acrylic resin) and samples made from bis-acryl composite resin (Integrity) and polymethylmethacrylate acrylic resin (Alike) were used in this investigation (Table I). Each material group contained 30 samples. For all 90 samples, a section of schedule-40 polyvinyl chloride (PVC) pipe (length, 1.5 in; diameter, 0.5 in) was used as a holding device. In the first group, 30 identical denture teeth with mechanical undercuts were placed on adhesive tape, and a section of PVC pipe was poured into the ring and around the sample. In the second group, a section of PVC pipe was filled with Integrity. After all materials had set, the testing surfaces of all samples were flattened with 600-grit sandpaper and sandblasted (microetched) by using 50-μm aluminum oxide with a microblasting unit (Basic Quattro IS no. 2955-1000, Renfert GmbH, Hilzingen, Germany) to duplicate the clinical preparation procedures typically performed on prefabricated denture teeth.

All material groups were bonded in the same fashion. The brackets chosen for this study were stainless steel APC PLUS (precoated with Transbond XT resin cement) maxillary lateral incisor brackets (0.022-in MBT Victory series) (3M Unitek, Monrovia, Calif). The testing surface of all specimens was dried with compressed air. Transbond XT Primer (3M Unitek) was applied to the testing surface in a thin film, and then a gentle burst of air was delivered with a chairside air-or-water syringe. Each bracket was positioned and pressed onto the testing surface in a consistent manner by using an orthodontic bracket applicator. Excess adhesive was removed with a dental explorer. The adhesive was photopolymerized by using a SmartLite PS LED curing light (Dentsply Caulk) for 10 seconds on the mesial and distal aspects of the bracket for a total light-curing time of 20 seconds. The output of the light-curing unit was tested with a curing radiometer (model 100, Demetron Research, Danbury, Conn) to ensure a minimum irradiance of at least 400 mW per square centimeter. The same operator (I.M.) performed all bracket-bonding procedures to ensure the consistency of the samples (Fig 1).

Each material group was divided into 2 testing subgroups: 15 samples were tested for shear bond strength 24 hours after bonding, and the other 15 samples were tested 1 week after bonding. All 90 samples were stored after bonding in distilled water at 37°C. The samples were mounted on a base jig and adjusted to ensure that their bracket bases paralleled the direction of the shear force to allow for standardized and secure placement during testing. Each bracket was subjected to a 90° shear force directed at the bracket base with a chisel-shaped rod attached to the end of a universal testing machine (model 5543, Instron, Canton, Mass) with a crosshead speed of 1.0 mm per minute until bonding failure occurred (Fig 2). For each sample, the shear bond-strength value in megapascals was...
calculated from the peak load at failure (in newtons) divided by the sample’s bonding surface area; the value of the surface area of the wire mesh of the brackets was reported by the manufacturer to be 9.48 mm² (personal communication by phone on December 12, 2006, with Darrell S. James, Senior Technical Service Engineer, 3M Unitek; dsjames@mmm.com).

After debonding, the principal investigator visually examined each sample with dental loupes (Orascoptic, Middleton, Wis) at 2.5-times magnification to evaluate the residual adhesive on the sample surface. The adhesive remnant index (ARI) was used as originally described by Årtun and Bergland¹⁵ to determine the location of bond failure. The ARI was scored for each debonded surface as follows: 0, no adhesive remaining on the specimen; 1, less than half of the adhesive left on the specimen; 2, more than half of the adhesive left on the specimen; 3, all adhesive left on the specimen, with a distinct impression of the bracket mesh.

An ARI score of 0 or 1 implied that adhesive failure occurred at the cement-provisional material interface; a score of 2 or 3 implied cohesive failure of the cement or bracket base-cement interface.

### Statistical analysis

The data were initially examined with exploratory data-analysis methods. A 2-factor analysis of variance (ANOVA) was used to test the main effects of the esthetic pontic materials and times of load test (24 hours or 7 days). The Tukey HSD post-hoc test was performed when indicated. Initial statistical analyses were performed at the α = 0.05 level of significance. The results of the ANOVA were confirmed by the Kruskal-Wallis ANOVA on ranks.

### RESULTS

Based on the results from the initial analysis with the 2-factor ANOVA, the data file was stratified and analyzed by using single-factor ANOVA tests and Student t tests to determine whether the differences in bond strength were statistically significant. The Bonferroni adjustment was applied to the alpha level, and P values less than 0.01 were considered statistically significant. The results obtained with the parametric tests were confirmed by using nonparametric tests (Mann-Whitney U tests) because of the nonnormality of some data. The ARI scores were tabulated and analyzed by using the chi-square test.

The 15 samples in each testing subgroup (total of 90 samples) provided 80% power to detect a small effect-size (0.3, or approximately 0.6 SD) difference for the main factor of time (24 hours vs 7 days), a small effect-size (0.335, or approximately 0.67 SD) difference for the main factor of tooth type (esthetic pontic material), and a small effect-size (0.335, or approximately 0.67 SD) for the interaction term when testing with a 2-factor ANOVA at the alpha level of 0.05 (NCSS PASS 2002).

All statistical analyses were performed with a software package (version 15.0 for Windows, SPSS, Chicago, Ill).

<p>| Table II. Shear bond strength values (MPa) for the experimental groups |
|---------------------------------|-----------------|---------------|--------|---------------|</p>
<table>
<thead>
<tr>
<th>Material group</th>
<th>Mean shear bond strength</th>
<th>Significant difference</th>
<th>SD</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denture tooth</td>
<td>5.3</td>
<td>3.3</td>
<td>4.5</td>
<td>2.1-13.3</td>
<td></td>
</tr>
<tr>
<td>Alike</td>
<td>6.5</td>
<td>2.6</td>
<td>5.9</td>
<td>3.6-11.4</td>
<td></td>
</tr>
<tr>
<td>Integrity</td>
<td>9.5</td>
<td>2.6</td>
<td>9.2</td>
<td>4.2-14.8</td>
<td></td>
</tr>
<tr>
<td>7 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denture tooth</td>
<td>5.5</td>
<td>2.1</td>
<td>5.6</td>
<td>3.3-10.2</td>
<td></td>
</tr>
<tr>
<td>Alike</td>
<td>11.3</td>
<td>4.7</td>
<td>12.4</td>
<td>2.7-17.7</td>
<td></td>
</tr>
<tr>
<td>Integrity</td>
<td>14.7</td>
<td>7.3</td>
<td>17.2</td>
<td>3.0-23.7</td>
<td></td>
</tr>
</tbody>
</table>

Fig 2. Mounted specimen ready to be tested.

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(P <0.001). Post-hoc testing indicated that the mean bond strength of the Integrity group was significantly higher than that of the prefabricated denture tooth and Alike material groups, which were not significantly different from each other.

When we evaluated the mean shear bond strength of the materials tested 7 days after bonding, the results indicated significant differences among the groups (P <0.001). Post-hoc testing showed that the mean bond strengths of both the Integrity and Alike groups were statistically similar, but they were significantly higher than that of the prefabricated denture tooth.

In each material group, the 1-day values were compared with the 7-day values. For the denture tooth material, the difference in means was not statistically significant (P = 0.78). For Alike, the mean bond strength was significantly higher on day 7 vs day 1 (P = 0.002). In the Integrity group, the significance for the differences in mean bond strength for day 7 compared with day 1 was P = 0.018. With the Bonferroni adjustment applied to the alpha level, the difference observed in the Integrity group was not considered statistically significant.

The analysis of the ARI scores showed no consistent pattern; therefore, no conclusions were drawn from these data (Table III).

**DISCUSSION**

Commonly used denture teeth and Alike materials are based on polymethylmethacrylate chemistry. Methyl methacrylates are linear polymers that undergo free-radical polymerization to form long, single-chain polymers. The primary differences between these materials relate to their densities and completeness of polymerization. Denture teeth are fabricated under high pressure and temperatures. This results in materials with greater density and fewer potential bonding sites. In contrast, Alike has lower density but more potential bonding sites. This might explain the improvements in bonding observed for Alike. Integrity is a bis-acryl polymer that is similar to the adhesive we used (Transbond XT). Bis-acryl materials are a combination of dimethacrylates as found in traditional composite resin-based cements and the methyl methacrylates in Alike and

![Image](https://example.com/image.png)

**Fig 3.** Means and standard deviations of shear bond strengths for the experimental groups at 24 hours (1 day) and 7 days. Error bars denote 1 SD.

<table>
<thead>
<tr>
<th>Material group</th>
<th>ARI score*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denture tooth</td>
<td>0 5 10 0</td>
</tr>
<tr>
<td>Alike</td>
<td>0 12 3 0</td>
</tr>
<tr>
<td>Integrity</td>
<td>4† 4 7 0</td>
</tr>
<tr>
<td>Denture tooth</td>
<td>0 6 9 0</td>
</tr>
<tr>
<td>Alike</td>
<td>0 13 2 0</td>
</tr>
<tr>
<td>Integrity</td>
<td>3† 1 9 2</td>
</tr>
</tbody>
</table>

*0, No adhesive left on the specimen surface; 1, <50% of the adhesive left on the specimen surface; 2, >50% of the adhesive left on the specimen surface; 3, all adhesive left on the specimen surface, with a distinct impression of the bracket mesh; †Failure occurred within the Integrity material.
the prefabricated denture teeth. The dimethacrylates (eg, bis-GMA) also undergo free-radical polymerization but, because of an additional reactive group, form cross-linked polymers. The greater cross-linked density of bis-acrylic materials results in improved mechanical properties. As a result of this similarity, bond strengths between these 2 materials were enhanced.

In this study, the null hypothesis was rejected because significant differences in shear bond strength were found between the pontic materials at the different time periods. Although Integrity had statistically higher bond strengths at day 1 compared with Alike, no difference was observed at day 7 between these 2 groups. When comparing the mean shear bond strengths among all groups at day 1 vs day 7, only the Alike group had significantly higher values on day 7 than on day 1. This result is most likely due to the material’s increasing polymerization from day 1 to day 7. Continued polymerization at the substrate-adhesive interface results in increased bond strength (from day 1 to day 7).

Reynolds suggested that a minimum bond strength of 6 to 8 MPa is adequate for most clinical orthodontic needs and is considered adequate to withstand masticatory and orthodontic forces. Our study was designed to evaluate bond strengths to provisional restorative materials; however, if a comparison is made to the previously reported bond-strength values to enamel, our data demonstrate that only Integrity and Alike consistently satisfy this acceptable range.

Among orthodontic practitioners, there is a common clinical practice of roughening the surface with a bur or a greenstone, or by sandblasting a prefabricated denture tooth before bracket placement to add mechanical retention. This might be an acceptable method to overcome the lower bond strengths observed with the denture tooth material, but this was not analyzed in our study.

Both Integrity and Alike would be more ideal materials for esthetic pontic fabrication during orthodontic treatment, because of higher shear bond strengths as compared with a prefabricated denture tooth (interpenetrating polymer network acrylic resin). However, the use of Integrity or Alike requires a unique armamentarium for efficient clinical use. After selection of the appropriate shade, we suggest the following 2 options for pontic fabrication.

1. Fabricate a polyvinylsiloxane mold of various tooth sizes that can be poured with Integrity or Alike as needed clinically. As an additional alternative, a prefabricated crown kit can be purchased and used.
2. By using the diagnostic casts, wax a pontic form with ideal shape and position, and make an impression of the arch segment with heavy-body polyvinylsiloxane impression material. The impression then can be used as a mold for fabrication of the tooth.

Integrity or Alike provisional could be used by prosthodontists or restorative dentists when fabricating provisional crowns for teeth requiring orthodontic movement (eg, extrusion or uprighting). This allows practitioners to take advantage of the higher bond strengths to orthodontic brackets or attachments. Particularly, Integrity would be beneficial when increased bond strength is required immediately after bonding. According to Young et al, “bis-acryl composite resin (Integrity) proved to be a predictable material for the efficient fabrication of provisional restorations, and this material was statistically superior to the [polymethylmethacrylate] resin” for the parameters tested.

When comparing Integrity and Alike, one should keep in mind that Integrity (a bis-acryl composite resin material) is preferred by many because of its superior handling characteristics. These include ease of manipulation, ease of repair or modification with composite resin, less porosity, reported low polymerization shrinkage, and good color stability compared with Alike (a polymethylmethacrylate acrylic resin material).

**CONCLUSIONS**

This study demonstrated the following.

1. When used as an esthetic pontic as part of a fixed orthodontic appliance, Integrity (bis-acryl composite resin) and Alike (polymethylmethacrylate acrylic resin) had significantly higher mean shear bond strengths compared with a prefabricated denture tooth (interpenetrating polymer network acrylic resin) at 7 days.
2. At 24 hours, Integrity had significantly higher mean shear bond strength than did either the Alike or the denture-tooth group; they were not significantly different from each other. Therefore, although Integrity demonstrated statistically significantly higher bond strengths at day 1 compared with Alike, no difference was observed at day 7 between these 2 groups.
3. Integrity and Alike require an additional armamentarium, but their use is indicated in clinical situations that require optimal bracket-attachment bond strength to a provisional restoration or pontic.
4. In each material group, when comparing 1-day values with 7-day values, the differences were statistically significant only for the Alike group: the mean bond strength was significantly higher on day 7 vs day 1 for this material.
We thank Anneke C. Bush for her statistical contributions and Rodney D. Phoenix for his editorial assistance.

REFERENCES