INFLUENCE OF SURFACE TREATMENTS ON SHEAR BOND STRENGTH BETWEEN COMPOSITE RESIN AND ACRYLIC RESIN DENTURE TEETH-AN IN VITRO STUDY

Ginnia Bhayana¹, Nidhi Duggal², Gaurav Atreja¹, Ashish Juneja³, Arun Kumar⁴

¹Department of Prosthodontics, ³M.M. University of Dental Sciences and Research, Mullana, Ambala, Haryana, India.
²Department of Prosthodontics, Government Dental College & Hospital, Patiala, Punjab, India.
⁴Department of Pedodontics & Preventive Dentistry, Post Institute of Dental Sciences, Rohtak, Haryana, India.

ABSTRACT
Visible light activated composite resins are preferred for various prosthodontic applications as restoration of fractured or debonded artificial teeth because of the advantages of excellent aesthetics, superior colour stability, improved wear resistance and minimum inconvenience to the patients. However, the bonding of composite resin to acrylic resin denture teeth has remained unpredictable. Various methods as acid etching, air abrasion, use of solvents or bonding agents have been reported to improve the bond strength of these two resins. But there is no consensus on the results obtained with different surface treatments. The purpose of this study is to evaluate the efficacy of different combinations of surface treatments used to improve the bond strength between light activated composite resin and acrylic resin denture teeth. Ninety test specimens of acrylic resin denture teeth of the same mold were prepared and divided into six groups, containing 15 samples each. The denture teeth were subjected to six different combinations of surface treatments including acid etching with 35% phosphoric acid, application of methyl methacrylate, bonding agent, aluminium oxide powder and flowable composite. Over all treated surfaces, light activated composite resin was applied in increments and cured. The shear bond strength of composite resin to acrylic resin denture teeth was determined and analyzed statistically.

INTRODUCTION
Fracture or detachment of acrylic resin denture teeth from the denture bases is a frequent and unresolved clinical problem in Prosthodontics, accounting for 20-33% of denture repairs. Artificial teeth may fracture or debond due to excessive biting forces in the mouth, fatigue failure, stress concentration, accidental trauma etc. It is desirable that not only the material used for repair of artificial denture teeth should match the original material in strength and shade but also the technique employed should be easy, quick and inexpensive.

Corresponding Author

Arun Kumar
Email: - drarun922@gmail.com
on partial denture metal frameworks, correction of worn occlusal contacting surfaces of posterior artificial teeth.

However, an adequate bond between composite resin and acrylic resin denture tooth which is essential for the success or longevity of these procedures has remained unreliable, inconsistent and unpredictable. Various surface treatments like acid etching, air abrasion, use of methyl methacrylate monomer, chloroform, acetone, silanes, bonding agent, flowable composite resins have been advocated to enhance the bond strength between composite resin and acrylic resin denture teeth.

Most of the studies have demonstrated that a bonding agent is essential for achievement of an adequate bond strength between the light-activated and heat polymerised resin. As regards the use of methyl methacrylate monomer, conflicting results have been reported. Lagouvardos et al9 and Lucena et al10 observed that surface treatment with air abrasion along with bonding agent had a synergistic effect on the bond strength of composite resin to artificial teeth. Considerable variations in the bond strength values have been reported in the literature.

So, a study has been planned to compare the efficacy of various surface treatments on the bond strength between composite resin and acrylic resin denture teeth so as to identify an optimal surface treatment which can enhance bonding.

MATERIALS AND METHODS

The study was conducted on ninety mandibular first molar acrylic resin denture teeth of the same mould.

The denture tooth will be mounted on to a rectangular wax mould (Fig.1). Wax mould with embedded acrylic denture tooth will then be invested in dental plaster (Fig.2). After setting of plaster and dewaxing, the mould space will be packed with heat cured acrylic resin and polymerized (Fig.3). The test specimen will then be cooled to room temperature, deflasked and finished.

Denture Tooth Preparation

The attached denture tooth will be milled to a diameter of 6mm (Fig.4) to standardize the bond surface area (Fig.5).

Ninety such specimens will be prepared and stored in distilled water for one week, cleaned and dried. These will be divided into six groups with each group containing fifteen test specimens.

Groups : Surface Treatment of Acrylic Resin Denture Teeth

Group 1. Acid etching (35 % phosphoric acid) and Bis- GMA based bonding agent application.

Group 2. Methyl methacrylate monomer and Bis- GMA based bonding agent application.

Group 3. Acid etching (35 % phosphoric acid), methyl methacrylate monomer and Bis - GMA based bonding agent application.

Group 4. Air abrasion with 50 um aluminium oxide and Bis- GMA based bonding agent application.

Group 5. Air abrasion with 50um aluminium oxide, acid etching (35% phosphoric acid) and Bis- GMA based bonding agent application.

Group 6. Acid etching (35 % phosphoric acid), Bis-GMA based bonding agent and flowable composite application.

Over all the treated surfaces of acrylic resin teeth, light activated composite resin of 4mm thickness was applied in increments and cured (Fig.6). After polymerisation, test specimens were stored in distilled water at room temperature for 7 days before testing.

Testing Procedure

The shear bond strength between composite resin and acrylic resin denture teeth was measured in a Universal Testing Machine (Instron) using a knife-edge shear test (Fig.7). A load parallel to the acrylic resin denture tooth and composite resin interface at a crosshead speed of 0.5 mm/minute was applied. The maximum load, at break, for each specimen (Fig.8) was divided by bonding area (mm²), to express the shear bond strength. i.e. \( \frac{\sigma}{\text{MPa}} = \frac{L}{A} \).

Where \( \sigma \) stands for shear bond strength (MPa)

L stands for load (N) required to cause fracture at composite resin-acrylic resin denture tooth interface.

A is the interfacial area (mm²), which is calculated using the formula:

\[
A = \pi r^2,
\]

where ‘r’ is 3 mm.

The results thus obtained will be analysed statistically.

OBSERVATIONS AND RESULTS

Table 1 depicts the values of the shear bond strength in six different treatment groups. Data were subjected to statistical analysis. Calculated mean and standard deviation of the original values are shown in Table 2.

The comparison between the mean shear strengths of the six groups is displayed with the help of a bar diagram (Fig. 9)

For testing significance of the differences in the mean values One-way Analysis of Variance (ANOVA) using F test statistic of the data, were carried out as shown in Table 3.

Thus, from the above analysis it can be summarized that:

A. Surface treatment with air abrasion, etchant and bonding agent (Group 5) exhibited significantly higher mean bond strength (43.0847 MPa) than the other groups.

B. The mean bond strength values for teeth treated with etchant, MMA monomer and bonding agent (Group 3) was statistically significantly greater than the teeth in Group 2 (methylmethacrylate monomer and bonding agent). Addition of etchant in Group 3 might have created greater roughening of the acrylic resin surface and hence improved bond strength.
C. Group 1 (etchant and bonding agent application), Group4 (air abrasion and bonding agent), Group6 (etchant, bonding agent and flowable composite application) demonstrated significantly higher mean bond strength values than group 2 (MMA monomer and bonding agent) which exhibited the least mean bond strength.

**Figure 1.** Wax blocks with mounted acrylic resin denture teeth.

**Figure 2.** Teeth embedded in the plaster adjacent to mould space (after dewaxing)

**Figure 3.** Packing of heat-cure acrylic resin material

**Figure 4.** Acrylic resin denture tooth milled to a diameter of 6mm

**Figure 5.** Air-abrasion of acrylic resin denture tooth in sandblasting machine

**Figure 6.** Light curing of composite resin placed over treated surfaces of acrylic resin denture tooth

**Figure 7.** Test specimens in Universal Testing Machine

**Figure 8.** Fracture at the interface of composite resin and acrylic resin denture teeth.
Table 1. Shear Bond Strength (MPa) of Individual Test Specimens

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Treatment Group 1</th>
<th>Treatment Group 2</th>
<th>Treatment Group 3</th>
<th>Treatment Group 4</th>
<th>Treatment Group 5</th>
<th>Treatment Group 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.46 MPa</td>
<td>16.83 MPa</td>
<td>29.92 MPa</td>
<td>25.53 MPa</td>
<td>50.01 MPa</td>
<td>27.23 MPa</td>
</tr>
<tr>
<td>2</td>
<td>21.08 MPa</td>
<td>16.20 MPa</td>
<td>29.85 MPa</td>
<td>27.80 MPa</td>
<td>42.94 MPa</td>
<td>24.12 MPa</td>
</tr>
<tr>
<td>3</td>
<td>20.09 MPa</td>
<td>15.28 MPa</td>
<td>27.59 MPa</td>
<td>26.38 MPa</td>
<td>53.48 MPa</td>
<td>25.25 MPa</td>
</tr>
<tr>
<td>4</td>
<td>19.38 MPa</td>
<td>15.63 MPa</td>
<td>30.06 MPa</td>
<td>28.22 MPa</td>
<td>48.60 MPa</td>
<td>23.91 MPa</td>
</tr>
<tr>
<td>5</td>
<td>21.01 MPa</td>
<td>15.91 MPa</td>
<td>29.57 MPa</td>
<td>26.18 MPa</td>
<td>49.94 MPa</td>
<td>22.56 MPa</td>
</tr>
<tr>
<td>6</td>
<td>21.22 MPa</td>
<td>17.19 MPa</td>
<td>33.25 MPa</td>
<td>37.21 MPa</td>
<td>47.18 MPa</td>
<td>23.27 MPa</td>
</tr>
<tr>
<td>7</td>
<td>20.80 MPa</td>
<td>16.41 MPa</td>
<td>37.07 MPa</td>
<td>34.59 MPa</td>
<td>41.17 MPa</td>
<td>23.13 MPa</td>
</tr>
<tr>
<td>8</td>
<td>19.81 MPa</td>
<td>14.29 MPa</td>
<td>31.97 MPa</td>
<td>29.57 MPa</td>
<td>39.54 MPa</td>
<td>26.46 MPa</td>
</tr>
<tr>
<td>9</td>
<td>18.74 MPa</td>
<td>17.55 MPa</td>
<td>34.02 MPa</td>
<td>26.03 MPa</td>
<td>39.40 MPa</td>
<td>24.76 MPa</td>
</tr>
<tr>
<td>10</td>
<td>19.88 MPa</td>
<td>15.56 MPa</td>
<td>30.27 MPa</td>
<td>29.92 MPa</td>
<td>39.76 MPa</td>
<td>24.12 MPa</td>
</tr>
<tr>
<td>11</td>
<td>21.01 MPa</td>
<td>16.90 MPa</td>
<td>33.74 MPa</td>
<td>27.23 MPa</td>
<td>39.47 MPa</td>
<td>23.98 MPa</td>
</tr>
<tr>
<td>12</td>
<td>21.57 MPa</td>
<td>14.71 MPa</td>
<td>29.98 MPa</td>
<td>25.25 MPa</td>
<td>40.04 MPa</td>
<td>22.63 MPa</td>
</tr>
<tr>
<td>13</td>
<td>20.72 MPa</td>
<td>17.26 MPa</td>
<td>35.44 MPa</td>
<td>29.85 MPa</td>
<td>39.12 MPa</td>
<td>26.03 MPa</td>
</tr>
<tr>
<td>14</td>
<td>21.50 MPa</td>
<td>12.45 MPa</td>
<td>33.40 MPa</td>
<td>33.25 MPa</td>
<td>38.98 MPa</td>
<td>23.84 MPa</td>
</tr>
<tr>
<td>15</td>
<td>22.21 MPa</td>
<td>14.71 MPa</td>
<td>31.65 MPa</td>
<td>31.05 MPa</td>
<td>36.64 MPa</td>
<td>24.90 MPa</td>
</tr>
</tbody>
</table>

Table 2. Showing Mean and Standard Deviation Values of Shear Bond Strength

<table>
<thead>
<tr>
<th>Test Groups</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th>95% Confidence Interval For Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Group No.1</td>
<td>15</td>
<td>18.46</td>
<td>22.21</td>
<td>20.4987</td>
<td>1.0732</td>
<td>0.2771</td>
<td>19.9043 to 21.093</td>
</tr>
<tr>
<td>Test Group No.2</td>
<td>15</td>
<td>12.45</td>
<td>17.55</td>
<td>15.792</td>
<td>1.36738</td>
<td>0.35305</td>
<td>15.0348 to 16.5492</td>
</tr>
<tr>
<td>Test Group No.3</td>
<td>15</td>
<td>27.59</td>
<td>37.07</td>
<td>31.852</td>
<td>2.5788</td>
<td>0.66584</td>
<td>30.4239 to 33.2801</td>
</tr>
<tr>
<td>Test Group No.4</td>
<td>15</td>
<td>25.25</td>
<td>37.21</td>
<td>29.204</td>
<td>3.55678</td>
<td>0.91836</td>
<td>27.2343 to 31.1737</td>
</tr>
<tr>
<td>Test Group No.5</td>
<td>15</td>
<td>36.64</td>
<td>53.48</td>
<td>43.0847</td>
<td>5.26123</td>
<td>1.35844</td>
<td>40.1711 to 45.9982</td>
</tr>
<tr>
<td>Test Group No.6</td>
<td>15</td>
<td>22.56</td>
<td>27.23</td>
<td>24.4127</td>
<td>1.37072</td>
<td>0.35392</td>
<td>23.6536 to 25.1717</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>12.45</td>
<td>53.48</td>
<td>27.474</td>
<td>9.26002</td>
<td>0.97609</td>
<td>25.5345 to 29.4135</td>
</tr>
</tbody>
</table>
Table 3. Analysis of Variance (ANOVA)

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degree of freedom</th>
<th>Mean of Squares</th>
<th>‘F’</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>6905.233</td>
<td>5</td>
<td>1381.047</td>
<td>159.715</td>
<td>O.OOO**</td>
</tr>
<tr>
<td>Within Groups</td>
<td>726.344</td>
<td>84</td>
<td>8.647</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7631.577</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Since the mean difference in the present study lies between 0.00 and 0.01, findings of the present study are highly significant i.e. all the six combinations of surface treatments show statistically significant difference in the bond strength values.

DISCUSSION

True adhesion has been the “Holy Grail” of dental restorative materials since decades. As with any bonding process, the bond strength of an adherent material to another is dependent on its ability to establish an intimate contact and form some kind of physical (electrostatic bonding), chemical (atomic or molecular bonding) or mechanical (material interlocking) bond at the interface. Indeed a combination of all these three types produces the strongest bond. When the adhesive joint consists of a ground denture tooth surface on one side (adherent or substrate) and the composite resin on the other side (adherent or adhesive), the surface conditioning of the adherend plays a pivotal role in adhesion between the two resins.

Various surface conditioning methods as acid etching, air abrasion, use of methylmethacrylate monomer, chloroform, acetone, silanes, bonding agent, flowable composite resins have been advocated to enhance the adhesion but the optimum surface conditioning method has never obtained consensus. Hence, the present study had been undertaken to compare the efficacy of various surface treatments on the bond strength between composite resin and acrylic resin denture teeth so as to identify an optimum surface treatment which would enhance bonding and could be recommended for the clinical success and longevity of the prostheses or restorations.

Bis-GMA based bonding agent was used as one of the components of all the surface treatment modalities investigated in the present study and it was observed that the range of bond strength values achieved with various surface treatments was between 15.79 and 43.08 MPa. Perhaps the bonding agent in addition to increasing micromechanical retention helped in the formation of chemical bond between the matrix and exposed filler particles and hence enhanced the bond between acrylic resin denture teeth and composite resin after various surface treatments.

Another surface treatment method employed in this study was air-abrasion with 50 µm Al2O3 in combination with bonding agent and / or etchant. The results of the present study exhibited that surface treatment with air abrasion, etchant and bonding agent (Group-5) achieved the highest bond strength value (43.08 ± 5.26 MPa). The bond strength of the test specimens in Group-4 (air abrasion and bonding agent) was also in significantly acceptable range i.e. 29.20 ± 3.55 MPa. The increased bond strength can be ascribed to the fact that sandblasting increased the surface area available for physical and chemical bonding between acrylic resin teeth and composite resin. Also, the air-abrasion might have removed the saturated surface layer and exposed the underneath layer with a higher surface energy. This would have improved the wettability of the acrylic resin denture teeth and hence enhanced the bond strength.

But the results of the present study revealed that the joint produced bond strength of 20.49 ± 1.07 MPa. The addition of air particle abrasion to etchant and bonding agent resulted in a highly statistically significant improvement in the bond strength from 20.49 ± 1.07 MPa to 43.08 ± 5.26 MPa. Even the combination of air-abrasion and bonding agent as surface treatment demonstrated statistically significantly higher mean bond strength (29.20 ± 3.55 MPa) than the combination of etchant and bonding agent (20.49 ± 1.07 MPa). Superior bond strength achieved with sandblasting might have been not only due to further increase in surface area and surface energy but also because of the embedding of alumina particles in the surface resulting in greater micromechanical retention.

Surface treatment with etchant, bonding agent and flowable composite (Group 6) significantly enhanced the bond strength value (24.41 ± 1.37 MPa) in comparison to use of etchant and bonding agent only (20.50 ± 1.07 MPa). The explanation lies with the ability of flowable composite resin to mediate a closer contact of condensing composite with the tooth surface. This technique seems to be a good alternative procedure in cases where the condensing material is rather stiff and an abrasive unit is not available.

Acrylic resin denture teeth are mainly composed of polymethylmethacrylate and polyethylmethacrylate. Because of the manufacturing process (heat curing and cross-linking), the degree of conversion is relatively high in acrylic resin denture teeth. It has been suggested that wetting of the heat polymerized acrylic resin surfaces with methylmethacrylate for three minutes improves the bonding as it dissolves the surface structure of polymethylmethacrylate. This provides free double bonds.
that can copolymerize with the composite material. As the polymerization process of methylmethacrylate and Bis-GMA follow a similar pattern of activation and cross-linking because of the similar reactive methacrylate group of molecules, some chemical bonding between composite and acrylic resin may occur, if cross-links are provided on the acrylic resin teeth for bonding to the composite. However, it is also possible that there is no occurrence of chemical bonding. Rather, methylmethacrylate monomer may swell the denture tooth, allowing the composite to penetrate into surface microirregularities and yielding a mechanical bond. In reality, there is probably a combination of chemical and mechanical bonding between the composite and the monomer treated acrylic denture teeth.

Surface treatment with a combination of methylmethacrylate monomer and bonding agent used in the present study exhibited the least bond strength i.e. 15.79±1.36 MPa as compared to other surface conditioning modalities. The results indicate that the use of monomer to soften the acrylic resin denture teeth perhaps did not provide sufficient active sites to react with composite resin. Also, the poor wettability property of the high viscosity composite material probably influenced the result in Group-2 (Monomer and Bonding agent). But even the minimum value (15.79 ± 1.36 MPa) of bond strength exhibited by surface treatment with monomer and bonding agent was comparable to the bond strength value essential for the longevity of the bond between composite resin and etched enamel (10 MPa to 21 MPa).

Although this in vitro study evaluated the effect of different surface treatments on the bond strength between acrylic resin denture teeth and composite resin, it does not simulate the ideal clinical conditions as dentures are exposed to the forces due to functional (mastication and deglutition) and parafunctional activities in warm and wet oral conditions. The use of simple rectangular shaped specimens rather than a complex denture design contributes further to the limitations of the present study and should be investigated in future. Though the experimental method does not exactly imitate the intraoral conditions, it does provide an effective means of comparing the influence of six different surface treatments on the shear bond strength between acrylic resin denture teeth and composite resin under controlled conditions.

CONCLUSION

On the basis of results and conditions of this study, following conclusions were drawn:

1) Surface treatment with a combination of air-abrasion, etchant and bonding agent application exhibited highest bond strength i.e 43.08± 5.26 MPa between acrylic resin denture teeth and composite resin.

2) The shear bond strength achieved with surface treatment using etchant, monomer and bonding agent was 31.85±2.57 MPa and with air-abrasion and bonding agent was 29.20±3.55 MPa.

3) The bond strength between composite resin and acrylic resin denture teeth after surface treatment with a combination of etchant and bonding agent was 20.49±1.07 MPa. Addition of flowable composite resin further improved the bond strength to 24.41±1.37 MPa.

4) Surface treatment with a combination of methylmethacrylate monomer and bonding agent exhibited the least bond strength i.e. 15.79±1.36 MPa as compared to other surface conditioning modalities.

In light of these findings, it has been observed that all the six different combinations of surface treatments investigated in the study were effective in producing an optimum bond between acrylic resin denture teeth and visible light cured composite resin. The shear bond strength values achieved with all the surface conditioning methods used were significantly higher or comparable to the bond strength values considered adequate for the successful durable bond between composite resin and human enamel (10 MPa to 21 MPa).

As per this study, a combination of air abrasion, acid etching and bonding agent appears to be the most promising method of surface conditioning to enhance the composite resin-acrylic resin denture teeth bond essential for the success and longevity of a restoration and prosthetic. In case of non-availability of air abrasion unit, a combination of other surface treatments used in this study may be employed as an alternative procedure to achieve an adequate bond between composite resin and acrylic resin denture teeth.

ACKNOWLEDGEMENT: NIL

CONFLICT OF INTEREST: NIL

REFERENCES


