Effect of repair resin type and surface treatment on the repair strength of heat-polymerized denture base resin

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Statement of Problem. Acrylic resin denture fracture is common in prostodontic practice. When fractured denture bases are repaired, recurrent fractures frequently occur at the repair surface interface or adjacent areas.

Purpose. The purpose of this study was to evaluate the effect of different surface treatments on the flexural strength of the acrylic resin denture base repaired with heat-polymerized acrylic resin, autopolymerizing resin, and light-polymerized acrylic resin.

Material and Methods. Ninety-six specimens of heat-polymerized acrylic resin were prepared according to the American Dental Association Specification No. 12 (65.0 × 10.0 × 2.5 mm) and sectioned into halves to create a repair gap (3.0 × 10 × 2.5 mm). The sectioned specimens were divided into 3 groups according to their repair materials. The specimens from each group were divided into 4 subgroups according to their surface treatments: a control group without any surface treatment; an experimental group treated with methyl methacrylate monomer (MMA group); an experimental group treated with airborne-particle abrasion with aluminum oxide particles of 250-μm particle size (abrasion group); and an experimental group treated with erbium:yttrium-aluminum-garnet laser (laser group). After the surface treatments, the 3 materials were placed into the repair gaps and then polymerized. After all of the specimens had been ground and polished, they were stored in distilled water at 37°C for 1 week and subjected to a 3-point bend test. Data were analyzed with a 2-way analysis of variance, and the Tukey honestly significant difference test was performed to identify significant differences (α=.05). The effects of the surface treatments and repair resins on the surface of the denture base resin were examined with scanning electron microscopy.

Results. Significant differences were found among the groups in terms of repair resin type (P<.001). All surface-treated specimens had higher flexural strength than controls, except the surface treated with the methyl methacrylate in the heat-polymerized group. A significant difference between the control and abrasion groups (P=.013) was found. The scanning electron microscopy observations showed that the application of surface treatments modified the surface of the denture base resin.

Conclusions. The repair procedure with heat-polymerized resin exhibited significantly higher flexural strength than that of the autopolymerized and light-polymerized resins. In addition, the airborne-particle abrasion with aluminum oxide particles of 250-μm particle size improved the flexural strength of the specimens tested. (J Prosthet Dent 2014;111:71-78)

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Clinical Implications

Based on the results of this study, heat-polymerized acrylic resin can be used to repair acrylic resin denture base. Autopolymerizing resin or light-polymerized acrylic resin may be the method of choice in a dental practice. This study also suggests that airborne-particle abrading the surface of acrylic resin denture base with 250-μm aluminum oxide particles enhances the repair.

Although acrylic resins have good esthetic properties and are easily manipulated, they have low fracture resistance,1-4 and fractured acrylic resin denture bases are often encountered.1,5 Midline fractures occur twice as often in maxillary prostheses as in mandibular prostheses.1,6-8 Extensive relief areas, hard and soft tissue undercuts, unbalanced occlusion, fatigue during mastication, and traumatic events (such as dropping the dental prostheses) induce fractures.1,2,7-12

Fractured denture bases are commonly repaired, because it is expensive and time consuming to remake the dental prosthesis. A satisfactory repair should have adequate strength,10,13-15 and color10,11,13,14 and should be easy to undertake,11,12 quick,10,11,13,14 dimensionally stable,10,11,13,15 and cost effective.10,11,13,14

Heat-polymerized,16 autopolymerizing,17 and light-polymerized acrylic resins15 are used in the repair processes of base materials. The mechanical and chemical properties of acrylic resins improve as the temperature during polymerization is raised.18 Autopolymerizing resins are usually preferred in the repair process because they can be applied in a short time and are inexpensive and easy to use.11,18

The ratio of the repair area strength to the original strength is 75% to 80% when heat-polymerized acrylic resins are used17 and 60% to 69% when autopolymerizing resins are used.9,16 Although some research studies7,9,19 have found that autopolymerizing resins have a lower flexural strength than heat-polymerized acrylic resins, other studies have found that they have similar flexural strengths.20-22

Light-polymerized acrylic resins have various advantages, such as superior strength, ease of fabrication, ease of manipulation, short polymerization time, and absence of liquid monomer.23-25 The use of light-polymerized acrylic resin systems for direct intraoral relining of removable dental prostheses and the fabrication of denture bases without flashing has recently become popular.25,26 Polyzois et al27 reported that the repair strength was 13 MPa for autopolymerizing resins, 21 to 34 MPa for heat-polymerized acrylic resins, and 40 to 44 MPa for light-polymerized acrylic resins. The authors concluded that the repair strength was higher in the heat-polymerized acrylic resins because the base and repair materials have similar chemical properties. Razavi et al19 reported that base materials stiffened by light have sufficient strength for use as relining materials in clinical applications.

Various mechanical and chemical surface treatments have been used to improve the bond strength between the base and repair materials.29-31 Bur grinding,32 airborne-particle abrasion with 250-μm aluminum oxide (Al2O3) particles, carbon dioxide laser application,33 immersion in methyl methacrylate,20,34,35 and treatments with organic solvents such as chloroform,30,31,35 acetone,16,20,29,31,36 and methylene chloride (dichloromethane)29,30 are among these processes. Recently, lasers have been found to provide a relatively safe and easy means of altering the surfaces of materials. Although lasers have not been used to roughen polymethyl methacrylate (PMMA) surfaces before a repair process, they have been used to etch metals before the application of porcelain.17

Methylene chloride has a carcinogenic potential18-42; therefore, ethyl acetate is used in chemical surface treatments as a safer alternative. The repair strength achieved by applying ethyl acetate for 120 seconds during the repair process was equal to that of applying methylene chloride for 5 seconds.33 Shen et al31 reported that chloroform exposure for 5 seconds was sufficient and that longer chloroform exposure impaired the structure of the repaired surface of the base material.

Some of the studies6,9-11,15,27,44-46 applied a 1.5- to 3-mm distance between the repair surfaces, whereas other studies allowed a 10-mm distance between the 2 surfaces.47 Beyli and von Fraunhofer46 reported that the color differences between the repair material and the denture base material decreased with a decline in the polymerization contraction level when the maximum distance between the repair surfaces was 3 mm.

Adhesion between the denture base material and the repair material may increase depending on the chemicals applied to the acrylic resin surface. These chemicals cause morphologic changes by roughening the surface. Normally, this roughness can be created by immersing the surface in an acrylic resin monomer.16,31,49

In spite of the high frequency of denture fractures, little information is available about the effects of surface treatments on the repaired prostheses. Therefore, the purpose of this study was to investigate the effects of various surface treatments on the repair strength between the baseplate and heat-polymerized, autopolymerizing, and...
light-polymerized acrylic resins used as repair materials. The first null hypothesis was that the repair resin type would increase the repair strength of the heat polymerized denture base resin. The second null hypothesis was that the chemical and mechanical surface treatments would increase the repair strength of the heat-polymerized denture base resin.

**MATERIAL AND METHODS**

A power analysis found that 96 specimens were needed to detect a significant difference among 3 repair resins and 4 surface treatments (a total of 12 groups) on the repair strength of a heat-polymerized denture base resin. Ninety-six rectangular heat-polymerized acrylic resin (DeTrey QC-20; Dentsply Ltd) specimens (65.0 × 10.0 × 2.5 mm) were prepared according to American Dental Association Specification No. 12 with conventional processing methods.

**Table I.** Two-way analysis of variance to evaluate significant differences among groups

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair resin</td>
<td>162098</td>
<td>2</td>
<td>81049</td>
<td>273</td>
<td>&lt;.001</td>
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<tr>
<td>Surface treatment</td>
<td>3184</td>
<td>3</td>
<td>1061</td>
<td>4</td>
<td>.017</td>
</tr>
<tr>
<td>Repair resin × surface treatment</td>
<td>5208</td>
<td>6</td>
<td>868</td>
<td>3</td>
<td>.012</td>
</tr>
<tr>
<td>Error</td>
<td>24905</td>
<td>84</td>
<td>296</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>497077</td>
<td>96</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table II.** Mean flexural strength and standard deviation for repaired acrylic resin specimens subjected to different surface treatments and use of various repair resins

<table>
<thead>
<tr>
<th>Treatment Groups</th>
<th>HP (MPa)</th>
<th>SD</th>
<th>AP (MPa)</th>
<th>SD</th>
<th>LP (MPa)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control, no treatment</td>
<td>106</td>
<td>21</td>
<td>21</td>
<td>9</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Abrasion*</td>
<td>118</td>
<td>17</td>
<td>53</td>
<td>22</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>MMA</td>
<td>100</td>
<td>26</td>
<td>36</td>
<td>13</td>
<td>27</td>
<td>13</td>
</tr>
<tr>
<td>Laser1</td>
<td>127</td>
<td>29</td>
<td>34</td>
<td>10</td>
<td>15</td>
<td>4</td>
</tr>
</tbody>
</table>

HP, repaired with heat-polymerized acrylic resin; AP, repaired with autopolymerizing resin; LP, repaired with light-polymerized acrylic resin; MMA, treated with methyl methacrylate monomer; X, mean; SD, standard deviation.

*Airborne-particle abrasion with aluminum oxide particles.

1Erbium:yttrium-aluminum-garnet laser.

The specimens were sectioned into 2 halves to create a repair gap (3.0 × 10 × 2.5 mm) and then divided into 3 equal groups (32 specimens per group) according to the repair materials: repaired with heat-polymerized acrylic resin (HP); repaired with autopolymerizing resin (AP) (Takilon; Rodent); and repaired with light-polymerized acrylic resin (LP) (Versyo.com HD; Heraeus Kulzer). The specimens in each group (HP, AP, and LP) were divided into 4 subgroups (8 specimens per group) according to the surface treatments: a group without any surface treatments (control group); an experimental group treated with methyl methacrylate monomer for 120 seconds (MMA group); an experimental group treated with airborne-particle abrasion with 250-μm Al₂O₃ for 10 seconds at a pressure of 0.2 MPa, from a distance of 10 mm (abrasion group); and an experimental group processed with an erbium:yttrium-aluminum-garnet (Er:YAG) laser (Doctor Smile Erbium & Diode Laser, Lambda SpA) at a wavelength of 2940 nm, a spot size of 0.8 mm, a pulse frequency of 10 Hz, a pulse energy of 150 mJ, and a pulse duration of 100 μs (laser group). The laser was applied (scanning) for 60 seconds under water irrigation. During the laser application, the distance from the laser tip to the specimen was 10 mm.

The surface-treated and control specimens that were sectioned into 2 halves were embedded in the denture flask, with a metal mold (3.0 × 10 × 2.5 mm) placed in the center of the repair gap for standardization. After the denture flask was opened, the metal mold that formed the repair gap was removed. HP, AP, and LP were applied to the repair gap of the surface-treated and control specimens.

The specimens in the HP group were polymerized by keeping the denture flask in a thermal chamber (Termotron P-100; Termotron do Brazil Ltda) for 9 hours once it reached boiling temperature (74°C) by using the long boiling method. The specimens in the AP group were polymerized by keeping them under pressure at 55°C for 15 minutes. This process was carried out to enhance strength and decrease porosity. The specimens in the LP group were polymerized by reapplying light with a UniXS polymerizing box (Heraeus Kulzer) for 3 minutes for a final polymerization after a light application of 60 seconds for prepolymerization. When the polymerization processes were complete, the specimens were carefully removed from the denture flask, and residual acrylic resin was removed with a tungsten carbide bur at low speed. The specimens were molded to the final shape with 600-grit abrasive paper under running water. All specimens were stored in distilled water at 37°C for 1 week before testing.

A 3-point bend test was performed immediately after removing the specimens from the distilled water and...
without drying the specimens. This test was carried out on a universal testing machine (Model 2519-106; Instron Corp). A custom-made stainless steel device with a 50-mm span distance between the 2 supports was used, and the crosshead speed was set at 5 mm/min. A load was applied in the center of the specimens (center of the repair area). The specimens were loaded until the first sound of a crack was detected, and the load (N) was recorded.

The flexural strength values of each specimen were calculated with the following formula: \( S = \frac{3WL}{2bd^2} \), where \( S \) is the flexural strength (in megapascals), \( W \) is the fracture load (in newtons), \( L \) is the distance between the supports (50 mm), \( b \) is the specimen width (10 mm), and \( d \) is the specimen thickness (2.5 mm).

To evaluate the effects of the surface treatments and repair resins on the surface of the denture base resin, 4 specimens (1 specimen each from the control, MMA, abrasion, and laser groups) were selected before repair, and representative fractured specimens from each group were selected after the 3-point bend test. These selected specimens were gold-sputtered and examined under a field emission scanning electron microscope (SEM) (Zeiss EVO LS 10; Carl Zeiss) at 10.0 kV. The SEM photomicrographs were made with ×2000 magnification for visual inspection. In addition, the nature of the failure was noted as adhesive (interface), cohesive (only at the repair material), or mixed (interface and repair material).

A 2-way analysis of variance (ANOVA) was used to study the effects of the repair resin type, surface treatments, and their interaction on the flexural strength, followed by the Tukey honestly significant difference test with a confidence level of .05 to determine the mean differences. The statistical analysis was performed with statistical software (SPSS v19.0; IBM Inc).

### RESULTS

The 2-way ANOVA results are presented in Table I. Significant differences were found for repair resin type (\( P < .001 \)), surface treatments (\( P < .05 \)), and their interaction (\( P < .05 \)). The mean and standard deviation values of flexural strength for each of the experimental groups are presented in Table II.

The flexural strength of the specimens repaired with HP, AP, and LP was different (\( P < .001 \)). The lowest flexural strength values were observed in the LP group (14 MPa to 27 MPa) and the highest in the HP group (100 MPa to 127 MPa).

All surface-treated specimens had higher flexural strength than the controls, except those treated with the
MMA in the HP group. A significant difference was noted between the control and abrasion groups ($P=0.013$). However, no significant differences were found among the control, MMA, and laser groups.

Representative SEM images of the control, MMA, abrasion, and laser group specimens before bonding are presented in Figure 1. The surface treatment resulted in irregularities and many small pits on the surface of the denture base resin. The SEM images of the representative surfaces of the fractured HP specimens are presented in Figure 2; AP specimens are presented in Figure 3; and LP specimens are presented in Figure 4. For all specimens, adhesive failure was observed.

**DISCUSSION**

This study evaluated the effects of repair resin type and surface treatment on the repair strength of a heat-polymerized denture base resin. For the repair resin groups, significant differences ($P<0.001$) were found. Therefore, the first null hypothesis was not rejected. For the surface-treatment groups, the analysis found a significant difference between the control and abrasion ($P=0.013$) groups. No significant differences were found among the control, MMA, and laser groups. Thus, the second null hypothesis was partially rejected.

Ogle et al. reported that light-polymerized acrylic resins had more accurate fit and higher strength than heat-polymerized acrylic resins. In this study, the highest repair strength was found in the HP group, and the lowest repair strength was in the LP group. Andreopoulos et al. found that repairs with light-polymerized Triad VLC resin (Dentsply Intl Inc) had a much lower strength than those with autopolymerizing resins. The authors concluded that the flexural strength was lower in the light-polymerized Triad VLC acrylic resin because this material has high viscosity and poor adhesion as a repair material.

The current study found that the specimens in the LP group have a lower repair strength than the specimens in the AP group. This result is compatible with the findings of Andreopoulos et al. These results may be attributable to a high rate of cross-linking between similar resin base materials and to poor interaction and lack of adhesion or cohesion between the LP repair material and the PMMA. The LP material may not penetrate the PMMA.

Some researchers have reported that exposing the repair surface to monomer increases the bond strength. Olvera and de Rijk found that a 4-minute exposure to monomer increased the fracture strength. Vallittu et al. established that immersing the repair surfaces for 180 seconds in methyl methacrylate increased the transverse strength.
compared with shorter exposures. Exposure to monomer softens the PMMA, enhances the spread of superficial fissures, and forms pits in the denture surface. As a result, the repair material diffuses into the bond surface and develops adhesion. The increased repair strength found with chemical surface treatments may be because of monomer infiltration into the pits and cracks.

The results showed that HP had the highest repair strength with the laser pretreatment, the AP with the abrasion pretreatment, and the LP with the MMA pretreatment. These surface morphologic changes may enhance the mechanical retention between the fractured surface and repaired acrylic resin.

The limitations of the study include the absence of artificial aging with thermal cycling and the use of rectangular specimens instead of more complex denture shapes. In vitro studies are limited in their ability to predict the success of a material or technique in a clinical situation. Further in vitro studies and clinical research are necessary to investigate the effects of different surface types on the bonding of the repair resin to the denture base resin.

CONCLUSIONS

1. The results showed that the HP group exhibited a significantly higher repair strength than those of the AP and LP groups.
2. The surface treatment to the repair surface improved the flexural strength, except for the surface treated with the MMA in the HP group.
3. Pretreatment with abrasion provided a significantly higher flexural strength than that found in the controls.

REFERENCES


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