Effects of Addition of Aluminum Oxide on Flexural Strength and Hardness of Acrylic Resins

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Abstract:
Purpose: Acrylic dentures frequently fracture during service due to their poor strength characteristics. The aim of this study was to evaluate the effects of adding 5%, 10% and 15% aluminum oxide powder on the flexural strength, surface hardness of a conventional heat-polymerized acrylic resin.

Materials and Methods: One of the commonly used conventional heat cure denture base resin (DPI) and high impact heat cure denture base resin (Lucitone) with incorporation of three different percentage of aluminum oxide concentration was studied in 4 groups of 10 samples each. A standard mould measuring 65 x 10 x 3mm³ (ISO 1567 standard) was obtained for the fabrication of 40 specimens that were divided into 4 groups; group-A was unmodified denture base resin (Control group), group-B, group-C and group-D were modified denture base resin with 5%, 10% and 15% by wt. aluminum oxide powder respectively. All specimens were stored in distilled water at 37ºC for 7 days. The flexural strength of these specimens was measured using 3-point bending test in a Universal Testing Machine. Hardness testing was conducted using shore hardness tester.

Conclusion: Reinforcement of the conventional heat-cured acrylic resin (DPI) and high impact heat cured acrylic resin (Lucitone) with 15% by wt.% Aluminum oxide powder significantly increased its flexural strength and hardness with no adverse effects.

Keywords: Conventional heat cure denture base resins; flexural strength; aluminum oxide powder; hardness.

I. Introduction

One of the most widely used materials in prosthetic dentistry is polymethyl methacrylate (PMMA). Since its introduction in dentistry, it has been successfully used for denture bases because of its ease of processing, low cost, light weight, and color-matching ability (1, 2). However, acrylic resin denture base materials have poor strength (3, 4).

Many attempts have been made to enhance the strength of acrylic denture bases including the addition of metal wires and cast metal plates (5-7). The primary problem with using metal wire is poor adhesion between the wire and resin (7). Although metal plates increase the strength, they may be expensive and prone to corrosion.

Mechanical reinforcement of acrylics has also been attempted through the inclusion of fibers and metal inserts (5, 8). Although the inclusion of the fibers produced encouraging results, this method has various problems including tissue irritation, increased production time, difficulties in handling, the need for precise orientation, and placement or bonding of the fibers within the resin (1, 9, 10).

In the case of metal inserts, failure due to stress concentration around the embedded inserts has been reported. Although it has been reported that untreated aluminum oxide (Al2O3) powder develops physical properties of high impact acrylic resin (11-13), there have been no investigations regarding the effect of Al2O3 powder on the mechanical properties of a conventional heat-cured acrylic resin. Therefore, we evaluated the effects of Al2O3 at three different concentrations on the flexural strength (FS), surface hardness of a conventional heat-cured acrylic resin and high impact heat-cured acrylic resin.

II. Materials and Methods

A custom tray made of self-cure acrylic material suitable for the stainless steel mold was fabricated. With the polyvinylsiloxane impression material, an impression of this mold was made and master cast was poured with improved dental stone, i.e. die stone (Kalrock). Modeling wax was placed in each of the compartment. Master cast was invested in the dental flask using dental stone following manufacturer's instructions. was carried out and mold was allowed to cool. A standard mold measuring 65 x 10 x 3mm³ (ISO 1567 standard) was obtained for the fabrication of 40 specimens which were divided into 4 groups of 10 each.
Effects of Addition of Aluminum Oxide on Flexural Strength and Hardness of Acrylic Resins

Fig A: stainless steel mold

Fig B: master cast

About 40 specimens of DPI heat cure resin and 40 specimens of LUCITONE heat cure resin were divided into 4 groups each:

**Group-A:** Unmodified heat cure denture base resin (Control group).

**Group-B:** Modified heat cure denture base resin with addition of 5% by wt. aluminium oxide powder.

**Group-C:** Modified heat cure denture base resin with addition of 10% by wt. aluminium oxide powder.

**Group-D:** Modified heat cure denture base resin with addition of 15% by wt. aluminium oxide powder.

Fig C: Lucitone heat cure material

Fig D: DPI heat cure material

Three concentrations (5%, 10% and 15%) of aluminum oxide powder (5-22 microns) were mixed with polymer. As per Ellakwa et al (12) and Sehajpal et al (2), for an even distribution of filler within the polymer matrix, aluminum oxide powder was mixed with resin powder and liquid monomer. The oxide powder and acrylic powder were thoroughly mixed using a mortar and pestle for initial mixing and blending, followed by hand tumbling in a plastic jar until a uniform color is achieved. When the mix had reached dough stage, it was packed into the molds and the flask was kept in bench press unit for bench curing for 30 mins and curing was done according to manufacturer's instructions. Specimens were stored in distilled water at 37º C for 7 days before test.

Fig E: Specimen

The flexural strength of the specimens were tested in universal testing machine. Load was applied at the center of the specimen at a cross head speed of 5 mm/minute, until it fractured.

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For hardness testing, to determine Vickers values, a load of 30 g was applied for 30 seconds to specimens using a digital hardness tester. Each specimen was subjected to three indentations (one at the center and two at the border), and the average value was calculated for each group.

The values obtained were subjected to statistical analysis using one way ANOVA followed by post hoc Tukey’s test for multiple group comparison and paired ‘t’ test for intra group comparisons.

### III. Results

The mean flexural strength of DPI heat cure resin group A is 78.2 MPa, group B is 79.4 MPa, group C is 82.3 and group D is 82.37. The mean flexural strength of LUCITONE heat cure resin; group A is 75.5 MPa, group B is 80.8 MPa, group C is 82.8 MPa and group D is 83.4 MPa. Lucitone added with 15% aluminum oxide by wt. is found to have highest flexural strength.

Hardness of DPI heat cure resin group A is 65.5 MPa, group B is 73.3 MPa, group C is 85.8 MPa, group D is 91.1 MPa. The hardness of LUCITONE heat cure resin group A is 66.6 MPa, group B is 71.8 MPa, group C is 81.9 MPa, group D is 97.3 MPa. Hardness is also highest with lucitone added with 15% aluminum oxide powder.

Table 1 shows the flexural strength values of the groups. Table 2 shows the graphical representation of the flexural strength values. Table 3 shows the hardness values of the groups. Table 4 shows the graphical representation of the hardness values. Table 5 shows the comparison between DPI and LUCITONE heat cure resin materials. Table 6 shows the graphical representation of comparison between DPI and LUCITONE heat cure materials.

### Table 1: Flexural strength values of the groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>F-Value</th>
<th>P-Value</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPI</td>
<td>9</td>
<td>78.2222</td>
<td>3.374455</td>
<td>16.216</td>
<td>0.000</td>
<td>Significant</td>
</tr>
<tr>
<td>AL2O3 5%+DPI</td>
<td>9</td>
<td>79.4777</td>
<td>2.133529</td>
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<td></td>
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<tr>
<td>AL2O3 10%+DPI</td>
<td>9</td>
<td>82.3</td>
<td>0.947365</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>AL2O3 15%+DPI</td>
<td>9</td>
<td>82.3777</td>
<td>1.428956</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONTROL+LUCITONE</td>
<td>9</td>
<td>75.58889</td>
<td>2.731503</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>AL2O3 5%+LUCITONE</td>
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<td>80.835956</td>
<td>2.016666</td>
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<td></td>
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<tr>
<td>AL2O3 10%+LUCITONE</td>
<td>9</td>
<td>82.85556</td>
<td>1.048941</td>
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<tr>
<td>AL2O3 15%+LUCITONE</td>
<td>9</td>
<td>83.45556</td>
<td>1.048941</td>
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Effects of Addition of Aluminum Oxide on Flexural Strength and Hardness of Acrylic Resins

Table 2: Graphical representation of the flexural strength values

![Graphical representation of flexural strength values](image)

Table 3: Hardness values of different groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>Average</th>
<th>SD</th>
<th>F-Value</th>
<th>P-Value</th>
<th>Decision</th>
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</thead>
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<tr>
<td>CONTROL DPI</td>
<td>9</td>
<td>65.6556</td>
<td>8.519236</td>
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<tr>
<td>AL2O3 5% + DPI</td>
<td>9</td>
<td>73.31111</td>
<td>3.917092</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>AL2O3 10% + DPI</td>
<td>9</td>
<td>85.858556</td>
<td>11.75601</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>AL2O3 15% + DPI</td>
<td>9</td>
<td>91.17778</td>
<td>13.61216</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONTROL LUCITONE</td>
<td>9</td>
<td>66.666666</td>
<td>8.039745</td>
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<td></td>
<td></td>
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<td>AL2O3 5% + LUCITONE</td>
<td>9</td>
<td>71.81818</td>
<td>4.929869</td>
<td>17.655</td>
<td>0.000</td>
<td>Significant</td>
</tr>
<tr>
<td>AL2O3 10% + LUCITONE</td>
<td>9</td>
<td>81.919191</td>
<td>4.8888892</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>AL2O3 15% + LUCITONE</td>
<td>9</td>
<td>97.363636</td>
<td>5.84658</td>
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</tr>
</tbody>
</table>

Table 4: Graphical representation of hardness values

![Graphical representation of hardness values](image)

Table 5: Comparison between Lucitone and DPI heat cure materials

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>T-Value</th>
<th>P-Value</th>
<th>Decision</th>
</tr>
</thead>
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<td>Hardness DPI</td>
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<td>2.7655</td>
<td>-0.125</td>
<td>0.9031</td>
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<td>LUCITONE 36</td>
<td></td>
<td>81.68689</td>
<td>3.6000</td>
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<td>Significant</td>
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<td>Flexure DPI</td>
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<td>78.85</td>
<td>14.25</td>
<td>-0.179</td>
<td>0.8545</td>
<td>Not</td>
</tr>
<tr>
<td>LUCITONE 36</td>
<td></td>
<td>79.43</td>
<td>13.23</td>
<td></td>
<td></td>
<td>Significant</td>
</tr>
</tbody>
</table>

Table 6: Graphical representation to compare Lucitone and DPI heat cure materials

![Graphical representation](image)
Effects of Addition of Aluminum Oxide on Flexural Strength and Hardness of Acrylic Resins

IV. Discussion

The ultimate flexural strength of a material reflects its potential to resist catastrophic failure under a flexural load. As a foundation, the acrylic resin materials should exhibit a high proportional limit to resist plastic deformation and also exhibit fatigue resistance to endure repeated masticatory loads (14-16). The denture base in a removable prosthesis with high flexural strength, flexural modulus, and a large yield point distance would help to resist torsional forces in function, leading to a longer clinical service life for the prosthesis. Carbon fibers have been added to the resin matrix and have proved to be successful in increasing the strength of the denture base (8). Despite producing successful reinforcement, the black color of the fibers impart to the resin can be unacceptable to some denture wearers.

Mullarky RH (17) studied the reinforcement of acrylic resin with aramid fibers. He was successful in enhancing the fatigue resistance of the aramid fiber reinforced acrylic resin denture base material. The yellow appearance of the fibers was difficult to mask within the denture, necessitating thick layers of acrylic resin that added significantly to the bulk of the denture.

Mahroo Vojdani, Rafat Bagheri (18) conducted a study which showed that addition of 2.5 wt% of untreated Al2O3 to a conventional heat-cured resin improved the mechanical properties of PMMA without essential additional processing steps. Therefore, the fabrication of dentures by this method is not time-consuming, which would help to observe routine use of indental laboratories due to its low cost and ease of handling and processing. Ellakwa (12) and colleagues have reported that reinforcing high-impact acrylic resin with untreated Al2O3 powder at concentrations of 5-20 wt% resulted in increases in both the flexural strength and thermal diffusivity of this high-impact acrylic resins. Their study also showed that the hardness increased in proportion to the weight percentage of the Al2O3 filler. The hardness significantly increased after incorporating 2.5 and 5 wt% Al2O3.

This finding is in agreement with previous investigators, who have concluded that reinforcing dental restorative resins and acrylic resin with ceramic particles can produce some improvements in the surface hardness (4, 5, 19, 20). This increase in hardness may have been due to inherent characteristics of the Al2O3 particles. Al2O3 possesses strong ionic interatomic bonding, giving rise to its desirable material characteristics, that is, hardness and strength (19, 21).

Aluminum oxide, commonly referred to as alumina, has high hardness, excellent dielectric properties, refractoriness, and good thermal properties make it the material of choice for a wide range of applications. Furthermore, the white color of aluminum oxide powder is not expected to affect adversely the esthetic appearance of denture base resins.

V. Conclusion

Flexural strength of conventional high impact heat cure denture base resin (group-A) increased with addition of increased percentage of aluminum oxide powder. Incorporation of 5% by wt. aluminum oxide powder to heat cure denture base resin (group-B) did not produce significant increase in flexural strength of conventional denture resin (group-A). Incorporation of 10% (group-C) and 15% (group-D) by wt. aluminum oxide powder to heat cure denture base resin significantly increased the flexural strength of denture base resin. Highest flexural strength was found with 15% by wt. incorporation of aluminum oxide powder to heat cure denture base resin (group-D).

Hardness increased with addition of increased percentage of aluminum oxide powder. Lucitone added with 15% by weight aluminum oxide is found to have the highest hardness values.

References

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