Transverse Strength of Reinforced Denture Base Resin with Metal Wire and E-Glass Fibers

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Abstract:
Statement of problem: Fracture strength of a denture base resin is of great concern, and many approaches have been used to strengthen acrylic resin dentures.

Purpose: The aim of this study was to measure the transverse strength of a heat polymerized acrylic resin, after reinforcement with metal wire and two types of glass fibers.

Materials and Methods: Forty rectangular specimens (65.0×10.0×3.3 mm) of a heat-cured acrylic resin were made according to ISO/FDI 1567. Group I (control group) consisted of 10 specimens with no reinforcement. Specimens in group II reinforced with sandblasted metal wires. Group III and IV strengthened with woven (Stick Net) and continuous unidirectional (Stick) fibers respectively. The specimens were polymerized according to manufacturer’s recommendation. The transverse strengths were assessed with a 3-point bending test at cross head speed of 5mm/min. One-way ANOVA was carried out to compare and detect any differences among groups (α=0.05).

Results: Mean transverse strength (SD) of unreinforced specimens was 85.44 (8.6) MPa. The transverse strength increased significantly to 97.97 (5.5) MPa, 109.69 (5.8) MPa, and 127.13 (6.4) MPa in Metal wires, Stick Net, and stick fibers groups, respectively.

Conclusion: The transverse strength of heat-polymerized denture base resin was enhanced considerably by using metal wire and glass fibers reinforcements. However, the addition of unidirectional glass fibers was significantly more effective method to improve flexural strength of denture base acrylic resin.

Key Words: Denture base resin; Transverse strength; Glass fiber; Metal wire

INTRODUCTION
One of the most widely used materials in prosthetic dentistry is polymethyl methacrylate (PMMA). Excellent appearance, ease in processing, and repairability, make poly methyl methacrylate as an excellent denture base material. However, the primary problem is its poor strength characteristics, including low impact and flexural strength [1-4].

Strengthening the acrylic resin prosthesis can be approached by modifying or reinforcing the resin. One method is to incorporate a rubber phase in the bead polymer which produces high impact resin but unfortunately the high cost of these materials restricts their use [5,6]. One of the most common reinforcing technique is the use of metal wires embedded in prosthesis [7,8]; however, the primary problem of this technique is poor adhesion between resin and wires [7].

Cast metal plates also have been used to replace some parts of the denture. Although
metal plates increase the flexural and impact strength, they may be expensive, and prone to corrosion; moreover, metal-reinforced dentures may be unesthetic as well [8]. Another approach is the reinforcement of acrylic resin dentures with fibers. Various types of fibers including carbon, Kevlar, glass, and polyethylene have been tested. Carbon and Kevlar fibers are useful in strengthening PMMA; however, they produce clinical problems such as, difficulty in polishing and poor esthetics [9-11]. Woven polyethylene fibers normally develop anisotropic properties to the composite. They are more esthetic but the process of etching, preparing and positioning layers of them may not be practical in the dental office [12]. Glass fibers are the most common form of all used fibers; they improve mechanical properties of denture base polymers, have easy manipulation, and they are esthetic [13-16]. Reinforcement with fibers enhances the mechanical characteristics of denture bases, such as the transverse strength, ultimate tensile strength and impact strength [13,15]. Alternatively it has shown that there is no difference in impact strength between acrylic resin reinforced with metal wires, electrical (E)-glass fibers and silanized fibers [7,15]. The aim of this study was to compare the transverse strength of a heat-cured denture base acrylic resin reinforced with metal wires, unidirectional glass fibers (Stick), and woven glass fibers (Stick Net).

MATERIALS AND METHODS
The selected denture base resin used in the present study was a heat-cured polymethyl methacrylate (Meliodent; Heraeus Kulzer Ltd, Berkshire, Germany). The study carried out with four test groups which contained 10 specimens each. Control group (I) consisted of rectangular plates (65.0×10.0×3.3 mm) of heat–polymerizing denture base resin specimens without any reinforcement. Specimens in group II reinforced with sandblasted Remanium (1.0 mm diameter) spring hard clasp wires (Dentalum, Pforzheim, Germany). The specimens in groups III and IV contained woven glass fiber of Stick Net (Stick tech Ltd, Turku, Finland) and continuous unidirectional glass fiber of Stick (Stick tech LTD Turku, Finland) as reinforcing material, respectively. This fiber reinforcement system was based on preimpregnation of fibers with a highly porous polymer, which allows good impregnation of fibers with polymer matrix in the end product. The acrylic resin polymer and monomer were mixed with the powder/liquid ratio of 2.2g/1.0ml. The unpolymerized acrylic resin dough was then pressed into the stainless steel mold (65.0×10.0×3.3 mm) and polymerized by placing the mold in 20°C±1°C water, the water temperature were raised up to 100°C±0.5°C for 30 minutes. All specimens were manipulated according to the manufacturer’s instructions. Metal wires were sandblasted using 50 to 250 µm aluminum oxide (AL₂O₃) with a 5.5 bars applied air pressure, in a conventional sand-blasting device. Sandblasted wires were cut into a length of 60.0 mm, and placed in the middle of PMMA resin dough. Each specimen was processed as explained for group I. The Stick (S) fibers were cut into length of 60.0 mm and the Stick Net (SN) fibers were cut into sheets (6.0×60.0 mm) in order to strengthen group III and IV respectively. Fibers were wetted with methylmethacrylate monomer for 10 minutes and placed approximately in the middle of molds and then the polymerization cycle was carried out the same as other groups. All 40 specimens were finished, with 600 and 500 grit silicon carbide paper and water, to a final dimension of 65.0×10.0×3.3 ± 0.1 mm. The widths and thicknesses of the specimens were measured by a digital vernier caliper (Mitutoyo, Kawasaki, Japan).
The transverse strength was evaluated according to the ISO/DIS 1567 International Standard [17] by the three-point bending test (Fig.1) using Universal testing machine (Lloyds LRX, Lloyds Instruments Ltd, Hants, United Kingdom) at a crosshead speed of 5 mm/min. The samples were placed on jigs 50 mm apart with their ends fixed so that any movements at the support were eliminated. They were then loaded at the center until fracture occurred. The ultimate flexural strength (MPa) of each specimen was determined with the following formula [13,14,16]:

\[
\alpha = \frac{3 \times f \times 1}{2 \times b \times h^2}
\]

Where \(\alpha\) is considered as transverse strength (MPa), \(f\) = the maximum load applied (N), \(l\) = the span between the two supports (mm), \(b\) = the width of the specimen (mm), and \(h\) = the thickness of the specimen (mm).

One–way analysis of variance (ANOVA) was used to determine statistical differences (\(\alpha=0.05\)) among the transverse strength of four groups. Data were analyzed by SPSS software (SPSS 11.5 for Windows, SPSS Inc., Chicago, IL).

RESULTS
The mean (SD) transverse strength of the unreinforced heat polymerized PMMA (group I) was 85.44 (8.6) MPa; and reinforcing the material with sandblasted wires (group II), SN fibers (group III), and S fiber (group IV) increased it up to 97.97 (5.5) MPa, 109.69 (5.8) MPa and 127.13 (6.4) MPa respectively. The results of statistical analyses were shown in Table I.

Using the Duncan method showed that, mean transverse strengths of all test groups have statistically significant differences (P<0.005). The analysis of data revealed significant difference between group I and group II, III and IV (P<0.005). Specimens reinforced with S fibers showed the highest transverse strength followed by SN fibers and finally by metal wires. The control group without any reinforcement exhibited the lowest strength value. Metal wire, SN fibers and S fibers increased transverse strength of PMMA, 14%, 30% and 50% respectively.

DISCUSSION
In the present study, wire reinforcement increased transverse strength of PMMA 14%, SN fiber reinforcement increased transverse strength 30%, and reinforcing with S fiber increased the transverse strength up to 50%.

The test specimens with the metal wire strengthener were clearly stronger (97.9MPa) than the specimens in group I (85.4 MPa). This is in agreement with earlier studies, with similar results [7,8,18]. The roughening of surface of the wires was assumed to enhance

Table I: Descriptive statistics of the transverse strength of heat polymerized PMMA groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>SD</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>85.47</td>
<td>68.64</td>
<td>93.60</td>
<td>8.65</td>
<td>2.74</td>
</tr>
<tr>
<td>II</td>
<td>97.97</td>
<td>85.42</td>
<td>102.89</td>
<td>5.50</td>
<td>1.74</td>
</tr>
<tr>
<td>III</td>
<td>109.69</td>
<td>101.72</td>
<td>121.21</td>
<td>5.85</td>
<td>1.85</td>
</tr>
<tr>
<td>IV</td>
<td>127.13</td>
<td>114.44</td>
<td>137.50</td>
<td>6.49</td>
<td>2.05</td>
</tr>
</tbody>
</table>
the fracture resistance. Vallittu and Lassila [7] showed that fracture resistance was significantly increased when the surface was roughened by sandblasting which could be due to better bonding between the wires and the resin. This is supported by the evidence of an earlier study, in which the positive effects of sandblasting on the retention were noted when retentive quality of a fixed prosthesis was investigated [19]. The use of heatless stone and separating disc treatment showed less increase in fracture resistance of acrylic denture base material as compared to the sandblasted surface [8].

The present study demonstrated the effect of glass fibers on the transverse strength of denture base resin. It has long been hypothesized that the addition of synthetic fibers to the monomer-polymer mixture may strengthen the resultant acrylic resin and several different types of fibers have been investigated. Among the many types of fibers, glass fibers considered to be suitable for strengthening the dentures [14-16]. If fibers are to be used to strengthen a polymer material, optimal adhesion between the fibers and the polymer matrix is essential. Impregnation of reinforcing fibers with resin allows fibers to come into contact with the polymer matrix. This is prerequisite for bonding of fibers to polymer matrix and thus for strength of the composite [21-27].

Internal voids formed in the acrylic resin-fiber composite are assumed to be caused by polymerization shrinkage of the acrylic resin monomer liquid inside the fiber strand or poor wetting of the fibers with acrylic resin [21]. The monomer in which the fiber strand is dipped before incorporation into the acrylic resin has a volumetric shrinkage of 21% and the acrylic resin that surrounds the fibers shrinks only 8% [22]. However, the increase in the acrylic monomer liquid in the fiber seems to reduce the surface area of void space. As a result, the poor wetting of the fibers might result in formation of void space in the acrylic resin-glass fiber composite. Poorly impregnated regions in the composite decrease mechanical properties of the composite [20,21]. The result of present study showed that silanized (E)-glass fibers could considerably enhance the transverse strength of dental polymers, which could be due to proper impregnation of fibers with resin polymer.

The other factors that are related to the strength of the fiber composite are the quantity of fibers in polymer matrix, the orientation of the fibers, and the adhesion of the fibers to polymer [20]. The effect of adhesion between the fibers and polymer matrix is an important aspect from a clinical perspective, since it has a great influence on the strength of the composite [16,21]. In the present study, the flexural strength of unreinforced and reinforced acrylic resin specimens were tested according to ISO /DIS 1567 [17]. When glass fiber was used, a clear improvement in transverse strength was found in comparison to unreinforced acrylic resin specimens. This finding is in agreement with results of previous studies [14-16,20]. The result of this study revealed that reinforcement of denture base resins with glass fibers or metal wires may be a useful approach to strengthening denture bases beyond their normal limits. Metal wires have a dark color and might pose an esthetic problem, therefore, glass fibers can be considered as the choice material for reinforcing acrylic resin denture base. Hence, glass fibers are strongly recommended in patients with heavy occlusal load or when fracture strength of denture base resin is of great concern. Nevertheless, in order to find the long-term data especially on clinical behavior of these new fiber reinforcement systems, more studies should be performed.

**CONCLUSION**

According to the results obtained in this study, the transverse strength of heat-polymerized denture base resin was considerably enhanced
by including either metal wires or glass fibers. Moreover, the flexural strength of specimens reinforced with continuous unidirectional glass fibers was significantly higher than that of metal wire or woven fiber reinforcements.

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REFERENCES