

Impact of Surface Treatment with Different Repair Acrylic Resin on the Flexural Strength of Denture Base Resin: An *In Vitro* Study

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ABSTRACT

Aim and objective: The aim and objective of the present study was to assess the flexural strength of denture base resin based on surface treatment with different acrylic resin repair materials.

Materials and methods: Totally, 120 heat-polymerized polymethyl methacrylate denture base resin materials which are rectangular shaped with the size of 65 mm × 10 mm × 2.5 mm were fabricated. 150 μm-sized alumina used for surface treatment. All the 120 heat-cured, surface-treated acrylic denture base resin samples were randomly divided into three groups. Group I: glass-fiber-reinforced auto-polymerizing acrylic resin, group II: auto-polymerizing acrylic resin, and group III: light-cured acrylic resin. A universal testing machine was used to test the flexural strength of the repaired specimens.

Results: A highest mean flexural strength (88.96 ± 0.31) was demonstrated by group I, followed by group II (72.18 ± 1.86) and group III (66.30 ± 1.02). ANOVA demonstrated a statistically significant inter-group difference. On multiple comparisons, using Tukey's *post hoc* test a statistically significant difference between groups I and II and between groups I and III was found.

Conclusion: After considering the limitations, the present study concluded that the highest flexural strength is shown by glass-fiber-reinforced auto-polymerizing acrylic resin than by auto-polymerizing acrylic resin and light-cured acrylic resin.

Clinical significance: Denture repair comprises of joining two fractured parts of a denture with a denture repair material. The success of denture repair depends on the adhesion phenomenon. The treatment of the surface can be accomplished using a suitable material which changes chemically and morphologically and thus promotes better adhesion.

Keywords: Auto-polymerizing resin, Denture repair, Flexural strength, Surface treatment.

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INTRODUCTION

The most commonly used denture base material in prosthodontic clinical practice is acrylic resin. The fracture of acrylic denture base is uncommon, none the less an inevitable problem of denture care. The repair of acrylic fracture could be performed easily and possess satisfactory repair strength. The acrylic resin of auto-polymerizing type is frequently used as a repair material because of its rapid polymerization and easy handling and properties. The high bond strength between auto-polymerizing acrylic repair and heat-processed denture base resin is not always presumable.¹

Various methods have been undertaken to solve complications related to broken dentures such as enhancing strength of the dentures post-repair including altering the denture material (high-impact resins) or strengthening it with different fibers. Different approaches include different edge profiles, for example, 45° bevel rounded, butt joint, knife-edge, inverse knife-edge, rabbet, inverse rabbet, lap, joints with mechanical retention, and ogee joints.² Also, various materials have been used in the restoration of broken/fractured denture bases, such as visible-light-polymerized, heat-polymerized, auto-polymerized, or microwave-polymerized acrylic resin.³

The broken denture is also subject to the mechanical and chemical factors present intraorally. The denture comes in continuous contact with the saliva and other beverages that

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are consumed. The difference in pH and temperature of these fluids contributes to worsening of the denture base's mechanical properties. The fluids present intraorally get absorbed into the polymer of denture and perform as a plasticizer, thus reducing the strength of the denture material.⁴

Many efforts have been made to enhance the bond strength of denture base, to repair acrylic resin involving chemical and mechanical treatments. Few authors have demonstrated improved bond strength by creating a diatoric recess, which is a conduit located in the denture base to act as a feature of mechanical retention. Some studies in the recent past have tested a denture base of acrylic resin surface treated with aluminum oxide particles, an airborne abrasive particle of size 50 μm . These studies demonstrated that airborne abrasive particles improved bond strength and particle size of larger size for air abrasion additionally increased the bond strength. Also referred as alumina possesses strong ionic inter-atomic bonding with most stable hexagonal alpha phase at elevated temperature. By the addition of alumina, there was proper distribution and bonding of the filler within the matrix which improved the flexural strength.⁵ Thus, this study was performed to assess the benefit of 150 μm -sized aluminum oxide particles on the flexural strength of denture base resin in different acrylic resin repairs.

MATERIALS AND METHODS

Samples Preparation

The present study was conducted in the Department of Prosthodontics Crown and Bridge, Rajah Muthiah Dental College and Hospital, India. Totally, 120 heat-polymerized polymethyl methacrylate denture base resin materials which are rectangular shaped with the size of 65 mm \times 10 mm \times 2.5 mm were designed. Based on the instructions given by the manufacturer, the mixing of PMMA acrylic resin was done using a 100 g to 43 mL of powder-liquid ratio. A stainless-steel mold was used to pack the resin at the dough stage. An acrylizer which is regulated based on temperature was used to heat-polymerize the resin. The temperature of the water was maintained for 90 minutes at 74°C, next by 100°C for 30 min. The denture flasks were let to cool down to room temperature after heat-curing. A 600-grit silicon carbide sandpaper was used to finish the resin specimens under running water coolant. The completed specimens were immersed in water for 48 hours prior to testing for water saturation.

All the 120 samples that were heat-cured, surface-treated acrylic denture base resin samples were randomly divided into three groups (each group having 40 samples):

- Group I: glass-fiber-reinforced auto-polymerizing acrylic resin,
- Group II: auto-polymerizing acrylic resin, and
- Group III: light-cured acrylic resin.

A vertical line was drawn on the prepared intact specimen using a marker pen to divide it into 2 equal parts; a 3 mm mark was made on the left and right at the top and bottom from the middle line. Based on these markings, the prepared intact specimens were cut vertically. A 600-grit silicon carbide sandpaper was used to grind the surfaces that had to be repaired. A delta blaster was used at 0.48 MPa emission pressure to surface treat all samples using an air abrasion with 150 μm -sized alumina at right angles to the surface from a distance of 5 mm for 10 seconds. Following this, they were cleaned in an ultrasonic bath for 4 minutes, to remove any traces of alumina particles, and stored in distilled water till the repair procedure starts.

Repair Procedures for Denture Base Acrylic Resin

Group I: Glass-fiber-reinforced Auto-polymerizing Acrylic Resin

Just before positioning into the central groove, the glass fibers (ADVANTEX™ Glass Fiber, Owens Corning India Ltd) were cut into 10 mm length and were stored for 10 minutes in the auto-polymerizing resin's monomer. Auto-polymerizing resin was next packed into groove and 3 mm space and then curing at room temperature was done.

Group II: Auto-polymerizing Acrylic Resin

A stainless-steel mold was used to hold the paired halves of acrylic denture bases. The consistent space of repair of 3 mm was sustained between segments; the acrylic resin of auto-polymerizing type (DPI RR Cold Cure) was mixed and introduced into the repair site in the free-flowing state based on the instructions of the manufacturer. A 600-grit silicon carbide sandpaper was used to finish the repair site after polymerization and samples were stored at 37°C temperature in water for 7 days.

Group III: Light-cured Acrylic Resin

Another 40 samples were positioned in the mold made-up of stainless steel, and the light-cured acrylic resin (Traid Dentsply) material was used to repair the gaps. Finger pressure was applied to adapt the material into the gap. They were kept in the light-curing unit initially for 5 minutes and then were taken out of the mold and cured for an extra 8 minutes on the other side. A 600-grit silicon carbide sandpaper was used to finish all the samples post-polymerization.

Thermocycling and Testing Procedure

All 120 samples were immersed in a water bath maintained at 5°C and 55°C and subjected to 2,000 cycles thermocycle stressing with a 30 seconds reside time. A universal testing machine was used to test the flexural strength of the repaired specimen. The acrylic resin samples were stabilized in the fixture which is a part of the machine. Every single specimen was introduced to the 3 point bending test at a 5 mm/minutes crosshead speed at a distance of 20 mm. The load was applied at right angles to the center of the repaired area. The load direction was comparable to the direction of load that affects the repaired complete denture of maxilla. The force needed to break the denture base was measured in kilograms. The kg/mm^2 flexural strength was changed to megapascals (MPa) by multiplying 9.8 with it so as to convert it into the international unit system. Force in $\text{kg}/\text{mm}^2 \times 9.8 = \text{force in MPa}$.

Statistical Analysis

A 20.0 Windows version of SPSS was used to perform the statistical procedures. The difference between the different groups was analyzed using ANOVA and Tukey's *post hoc* statistical tests. The level of significance was determined using *p* value less than 0.05.

RESULTS

The mean flexural strength of all acrylic resin repairs was shown in Table 1. A highest flexural strength (88.96 ± 0.31) was recorded in group I (glass-fiber-reinforced auto-polymerizing acrylic resin) followed by 66.30 ± 1.02 in group II (auto-polymerizing acrylic resin), and 72.18 ± 1.86 in group III (light-cured acrylic resin).

The comparison between mean flexural strengths of all acrylic resin repair groups is as shown in Table 2. Group I specimens

Table 1: Mean flexural strength of all repair acrylic resin

Groups	n	Mean ± std. deviation
Group I—glass-fiber-reinforced auto-polymerizing acrylic resin	40	88.96 ± 0.31
Group II—auto-polymerizing acrylic resin	40	72.18 ± 1.86
Group III—light-cured acrylic resin	40	66.30 ± 1.02

Table 2: Comparison of mean flexural strength of all repair acrylic resin groups

Groups	Mean ± SD	Std. error	F	p value
Group I—glass-fiber-reinforced auto-polymerizing acrylic resin	88.96 ± 0.31	0.1124	28.120	0.001
Group II—auto-polymerizing acrylic resin	72.18 ± 1.86	0.0409		
Group III—light-cured acrylic resin	66.30 ± 1.02	0.0204		

Table 3: Multiple comparisons using Tukey's *post hoc* test

Groups	Compared with	Mean difference	Sig.
Group I	Group II	16.78	0.001
	Group III	22.66	0.001
Group II	Group I	-16.78	0.001
	Group III	5.88	0.07
Group III	Group I	-22.66	0.001
	Group II	-5.88	0.07

showed a maximum mean flexural strength (88.96 ± 0.31) compared to group II (72.18 ± 1.86) and group III (66.30 ± 1.02). ANOVA demonstrated a statistically significant inter-group difference.

The multiple comparisons between different acrylic resin repair groups using Tukey's *post hoc* test as shown in Table 3. Groups I and II, and groups I and III demonstrated statistically significant difference.

DISCUSSION

In most of the cases, complete denture fracture is an emergency regardless of the etiology and it requires immediate care. The most basic need of any denture wearer is direct repair of denture. The use of self-cured acrylic resin to repair the broken denture has been common since long as the time taken to repair is less and is cost-effective too.⁶

The various materials used to repair a fractured denture are visible-light-polymerized resin, heat-cured acrylic resin, auto-polymerizing acrylic resin, and auto-polymerizing acrylic resin reinforced with glass fibers. The optimum selection of material depends on the bond strength to be gained with the repair material, working time, and the grade of dimensional stability sustained during and subsequent repair.⁷

Many of the dentures are repaired usually using a quick and simple method use of resin. The strength of auto-polymerizing acrylic resin repaired dentures was about 60–65% than the true strength of the denture, while it was 75–80% strength of the original

material for dentures repaired using heat-polymerized acrylic resin. The denture repairs by means of heat-cured acrylic resins are done very rarely due to prolonged treatment time and requirement of a custom split cast gypsum mold.⁸

In this study, glass-fiber-reinforced auto-polymerizing acrylic resin demonstrated the highest flexural strength, next only by auto-polymerizing acrylic resin and light-cured acrylic resin. In our study, 10 mm glass fibers were taken to strengthen the auto-polymerizing resin repair material. The glass fiber reinforcement led to higher flexural strength of repaired dentures (88.96 ± 0.31) than that after thermocycling in other groups.

Different glass fiber concentrations of auto-polymerizing resin were used by Keyf and Uzun.⁹ The addition of glass fiber led to higher transverse strength than control. This could be because the glass fibers may avoid progression of crack or due to the superior modulus of elasticity of glass fibers (which accepts majority of stresses without alteration) or it could be both. These results have been confirmed by the results we obtained. Unlike the results obtained by this study, Minami et al.¹⁰ demonstrated a lower flexural strength in the glass fiber reinforcement-repaired specimens than the control.

The measurement of the gap between the two broken fragments should be at least 3 mm so as to reduce the bulk of repair material used. This would further reduce the differences in color between repair material and denture base. Additionally, the degree of polymerization shrinkage reduces with reduction in the bulk of repair material.¹¹

The bond strength between the repair material and denture base should be as good as that of the original denture base resin. Nevertheless, the success of denture repair relies on the bond between the denture base and repair material. Mechanical treatment of the surface before denture base repair leads to an improvement in the flexural strength of the denture base materials significantly. This finding is in accordance with the finding in a trial by Minami et al.¹⁰ in which the bond strength increased significantly between an auto-polymerizing resin and the denture base resin, with the mean bond strength of the repaired denture being 8.2 MPa. Additionally, Jagger et al.¹² found that the friction between the repair material and the denture base increases with a rough surface needing extra debonding force at the boundary.

In this study, all the samples were exposed to thermocycle stressing by being submerged into water bath at 5°C and 55°C for 2,000 cycles with a residing time of 30 seconds. It has been established that the strength of a denture repair may depend on time. As per the trials conducted by Harrison et al.,¹³ Aydogan Ayaz E and Durkan R,¹⁴ strength of auto-polymerizing acrylic resin repair is comparatively weak within 1 hour of completion of laboratory procedure. The specimen pairs attained optimum strength between 1 day and 1 week of submerging in water. It was found by Razavi et al.¹⁵ that visible-light-polymerized resin's flexural strength increased significantly post-48 hours of submerging in water. Evidence suggests that the repaired dentures usually do not reach their optimum properties the ensuing day and because of this the repaired denture is preferably not returned to the patient for a minimum of 24 hours.¹⁶

The limitation of the present study design is the absence of simulating clinical conditions as the tested specimen was not same as the original denture conformation. Additionally, the present study could not simulate repeated mechanical stressing generated during mastication which is unavoidable with repaired dentures.

More research which closely simulates the clinical environment has to be conducted in the future.

CONCLUSION

After considering the limitations, the present study concluded that the highest flexural strength is shown by glass-fiber-reinforced auto-polymerizing acrylic resin than by auto-polymerizing acrylic resin and light-cured acrylic resin.

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