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Original Research Article

Comparative evaluation of flexural strength of heat polymerized acrylic resin denture base material repaired with auto- polymerized acrylic resin using surface treated reinforcement materials – An in vitro study

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ABSTRACT

Aim: The purpose of this vitro study was to comparatively evaluate the flexural strength of repaired denture base resin using different surface treated reinforcement materials.

Materials and Methods: According to ADA specification No. 12, typical heat polymerized acrylic resin specimens were created, and various repairs were made to them. Autopolymerizing resin was used for repair. The flexural strength was evaluated using the INSTRON universal testing equipment on a total of 90 samples (with 15 samples in each group).

Result: In this study the highest value of flexural strength was obtained for group in which the reinforcement was done with surface treated half round wires that were sandblasted, etched followed by application of alloy primer.

Conclusion: Specimens repaired with reinforcement increases flexural strength. Reinforcement with silanized woven roving e glass fibers showed significant increase in flexural strength compared to unreinforced specimens. There was no statistical difference between the samples repaired with sandblasted wires and etched wires group.

1. Introduction

Since time immemorial, dentistry depended to a large extent on naturally occurring materials for the fabrication of dentures to rehabilitate partial or complete edentulous patients. Acrylic resin denture base fracture is a frequent complication in clinical practice.[1,2] The repair of the fractured prosthesis can be accomplished using acrylic resins that are light polymerized, auto polymerized, heat polymerized, and microwave polymerized. The most common, quick, and straightforward repair technique is the use of auto polymerizing acrylic resin, despite numerous other procedures having been suggested. These materials all share the disadvantage of having weak fracture resistance. In order to address this issue and improve the tensile strength of denture bases mended with autopolymerizing glue, a variety of reinforcements, such as glass fibres.[3,4]

Satisfactory repairs must be easy and effective to serve the purpose successfully. However, the primary problem is its poor strength characteristics, including flexural and impact strength. A strong bond between the denture base resin and the repair resin is necessary to achieve the best repair strength. This study uses a variety of surface-treated materials in an effort to identify the best technique for mending broken dentures. Using silanized e-glass fibres, half-round wire treated with sandblasting, an etching solution, and primer, which can produce long-lasting results

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and stop the fracture from recurring, we have compared the flexural strength.

2. Materials and Methods

The study was carried out at V.S.P. M's Dental College and Research Centre, Nagpur. The approval was obtained from the Institutional Ethics Committee. The duration of the study was 6 months.

In this study a total of 100 samples were prepared and were divided into four groups. Each group included 25 samples.

Group A- Control group – Unreinforced specimens –(C)

Group B- Reinforced by using salinized woven roving E –glass fiber (GF)

Group C- Reinforced by using half round wire treated with sandblasting followed by application of primer (SW)

Group D- Reinforced by using half round wire treated with etching solution followed by application of primer (EW)

2.1. Metal die preparation

Two brass metal dies of dimension 31 mm in length, 13mm in width, 3 mm in depth were fabricated in pair.

1. Left segment
2. Right segment

The left segment had a bevel 5 mm long of 45^0[5] on the right side, similarly right segment had a bevel, 5mm long of 45^0 on the left side.

These metal dies had a threaded hole at the center to facilitate easy removal from stone mold, using screws engaging the threads (Figure 1).

2.1.1. Customized stainless steel metal plate

For securing the acrylic segments for repair procedure a stainless-steel customized metal plate was fabricated. Two threaded holes of diameter 6 mm each were placed at a distance of 65mm from each other, such that a gap of 3mm[6] was maintained as a repair area between the two acrylic segments during repair procedure. These acrylic segments were secured with a threaded screw and a washer. The repair area was supported with two metal plates (height 3mm) on either side.

2.1.2. Preparation of gypsum mold to obtain the specimens

Gypsum molds were prepared with preformed brass metal dies. The dies were engaged with a screw and gently teased out from the investing material. The mold cavities thus obtained were used for the preparation of heat polymerized acrylic resin samples.

2.1.3. Preparation of polymethylmethacrylate resin specimens

Conventional heat polymerizing denture base material (DPI) was used. According to manufacturer's recommendation monomer and polymer was mixed in ratio of 1:2.5 by weight. Final closure was done under hydraulic bench press, and it was kept under pressure of 3000 psi (according to manufacturer). The flask was clamped and maintained under pressure for 1 hour[7] to allow proper penetration of monomer into the polymer, and for even flow of material. The temperature was raised slowly up to 740C held for 2 hours, then raised to 1000C and was maintained for 1 hour.[8] After completion of this short curing cycle, the flask was removed from the water bath and allowed to bench cool at room temperature prior to deflasking.[9] The cured specimens were carefully removed and were then finished.

2.1.4. Making a groove for the placement of reinforcement material

To make a place for the reinforcement material, a groove 4mm wide, 2mm deep and 15 mm long on the beveled side with circular ends was prepared using a straight fissure carbide bur (ssw760) under copious water irrigation, which was standardized by using rubber stopper and a customized metal plate. (Plate IV)

2.2. Preparation of the specimens

2.3. Group A – Control group (unreinforced specimens) (Plate IV)

A pair of polymethylmethacrylate resin specimen was placed on a customized metal plate to maintain a 3 mm gap,[6] by placing the bevel surfaces facing each other, then the interface surfaces were wetted with autopolymerizing monomer for 180 seconds[10] with a camel hairbrush (No. 0) and the gap was repaired with sprinkle on method.[11] Since the repair compound lost its surface glaze after one hour, a small amount extra was preserved for polymerization shrinkage and finishing.[12] Then, in accordance with the manufacturer's instructions, these specimens were imbedded in a plaster block and stored in a pressure pot at 950C and 1.5 bars of pressure for 3 minutes. The samples were completed after repairs and kept in distilled water at room temperature for a week[13] before testing.

2.4. Group B - Reinforced by using silanised woven roving e glass fiber (Plate IV)

In this group, specimens of polymethyl methacrylate resin were reinforced with silanised e-glass fibers. The e glass fibres were uniformly thick and cut into 30mm lengths. These were then put into the groove after being submerged in methyl methacrylate (monomer) of autopolymerizing resin for 10 minutes.[14] The fibre was then positioned in the groove's centre, and the specimens were repaired and stored in the same way as previously indicated.

2.5. Group C – Reinforced by using half round wire treated with sandblasting followed by application of primer (Plate IV)

In this group, specimens of polymethylmethacrylate resin were reinforced with half round wire (remamium) of dimensions 1.75mm (width) × 0.90 mm (height) in diameter. The wires were cut into 30 mm in length which were air abraded with 50 microns aluminum oxide particles and the air pressure applied was 5.5 bars[15] for 1 min[16] and at a distance of 15mm which was standardized by using a customized jig. After sandblasting, all wires were ultrasonically cleaned in distilled water for 5 minutes and were air dried. Alloy primer[17] was applied directly over the wire surface with a brush in one direction on both the sides and it as allowed to dry for 10 seconds according to manufacturer's instruction on a customized stand. Then the surface treated metal wire was placed in the center of the groove and the repair, storage was done before testing in a similar manner as mentioned above.

2.6. Group D - Reinforced by using half round wire treated with etching solution followed by application of primer (Plate IV)

In this group, specimens of polymethylmethacrylate resin were reinforced with half round wire (Remamium) of same dimensions. These wires were then immersed in a etch solution (concentrated H_2SO_4 27.5 %, sodium dichromate 7.5 % distilled water 65 percent) for 15 minutes at 65^{O}C in an incubator.[18] After etching, all wires were ultrasonically cleaned in distilled water for 5 minutes and were air dried. Alloy primer was applied, and the samples were repaired and stored before testing in a similar manner mentioned above.

2.6.1. Testing of specimens – (Plate IV)

Flexural strength was tested with INSTRON universal testing machine (Star Testing System, India) at a 5.0mm/minute crosshead speed. The specimens were supported by 50mm-span jigs. The centre of the mended area was loaded. As the flexural tests progressed, stress-strain curves were produced. The chart was used to establish the greatest force that may cause a fracture, which was recorded as a fracture load in Newtons, and the flexural strength was calculated in MPa.

3. Results

3.1. Statistical analysis

Flexural strength was presented as Mean ± SD. Median and Range was also calculated for non-normalized data. Flexural strength was compared among 4 different groups by performing one-way Kruskal-Wallis ANOVA test for non- normalized data. Multiple comparison (Wilcoxon rank sum test) was carried out to find significant difference among any two groups. All the tests were 2 sided. $p<0.05$ was considered as statistical significance. Statistical analysis was done using statistical software STATA version 10.0. (Table 2)

It was observed that the mean flexural strength of Group C (SW) was highest (94.4) followed by Group D (EW) (89.39), Group B (GF) (75.60) and then Group A (C) (34.05) (Table 1)

The median values of flexural strength of Group C (SW) was highest (93.62), followed by Group D (EW) (83.3), Group B (GF) (76.3) and then Group A (C) (36.92) (Table 1 and Figure 2)

1. Flexural strength of Group B, Group C and Group D ($p<0.0001$) was highly significant than Group I (Table 3)
2. Flexural strength of Group C was highly significant ($p<0.0001$) with Group II (Table 3)
3. Flexural strength of Group B and Group D was significant ($p=0.0107$). (Table 3)
4. Flexural strength of Group C and Group D ($p=0.1073$) were not significant. (Table 3)

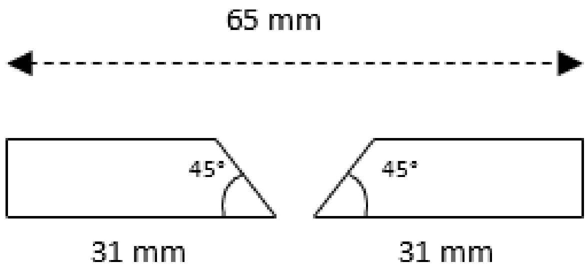

Fig. 1:

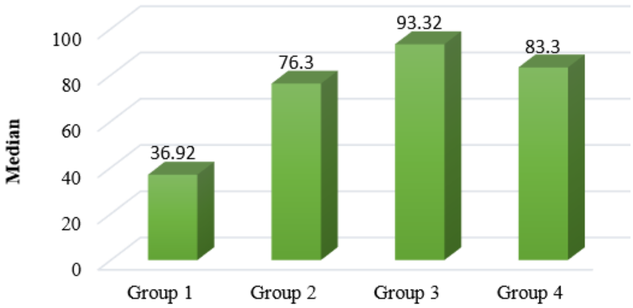

Fig. 2:

Table 1: Summary statistics of flexure strength of 4 groups

	Group 1	Group 2	Group 3	Group 4
Mean	34.05	75.60	94.4	89.39
Median	36.92	76.3	93.62	83.3
SD	10.72	14.92	13.36	15.60
Range	8.88-50.3	48.2-99.69	75.52-120.01	71.08-123.05

Table 2: Comparison of flexure strength of 4 Groups. (One-Way ANOVA by K-Wallis Test)

K-Wallis statistics	p-value	Significance
Chi2=64.54	<0.0001	Highly significance

Table 3: Multiple comparison of flexural strength between 4 groups (Wilcoxon Rank Sum Test)

	Multiple comparison					
	Group 1 vs. Group2	Group 1 vs. Group3	Group 1 vs. Group4	Group 2 vs. Group3	Group 2 vs. Group4	Group 3 vs. Group4
Z-statistics	6.025	6.064	6.064	3.842	2.551	1.610
p-value	<0.0001	<0.0001	<0.0001	<0.0001	0.0107	0.1073
Significance	Highly significance	Highly significance	Highly significance	Highly significance	Significance	Not Significant

4. Discussion

Fractures in dentures result from two different types of forces, namely, flexural fatigue and impact. Midline fracture of a denture base is a flexural fatigue failure.[19]

A persistent issue in prosthodontics is the breakage of acrylic resin dentures. According to studies, more than half of newly made dentures cracked within the first three years.[20] These broken dentures need to be fixed, sometimes as a temporary fix and other times as a permanent fix.[21]

Repairing a broken denture foundation should be quick, simple, and affordable while also having the same strength and colour as the original material.[11,21]

After being fixed using the heat-curing approach, the heat-cured dentures showed significant changes in contour, whereas the self-curing restorations produced far fewer alterations.[22] Given the aforementioned information, auto polymerizing resin was used to repair acrylic resin test specimens.

The type of joint utilised in the repair and the impact of various types of repair surface designs are two of the main elements affecting a repair's strength. It was found that 45-degree bevel joints greatly boosted the transverse strength. John E. Ward et al (1992)[23] Considering this fact this joint was used in this study.

A gap of 3mm was kept between the two heat polymerizing acrylic resin strips to be repaired, which was in accordance with the results of the study by M.S Beyli (1980)[6] by doing this, the bulk of repair material was minimized.

By the support of the study of Sarmistha Banerjee et al (2009)[24] who studied that All test specimens were stored in pressure pots prior to testing because pressure-pot curing increased the tensile bond strength over bench curing.

Silanization of woven glass fibers enhances the adhesion between the fibers and acrylic resin having a 450 bevel joint[25–27] So based on all these supportive studies we had used silanised woven roving e glass fibers.

According to some studies, the combination of autopolymerizing resin reinforced with semicircular wire had the most noticeable effect on the specimens' ability to withstand fracture. They also claimed that the most effective method for all metal wires was sandblasting, which was followed by the application of metal conditioner.[28–31] Therefore we had used half round wire which was sandblasted treated with 50um sand followed by application of alloy primer.

Microscopic retention, which showed a more marked effect on flexural strength, suggested chemical etching[32] therefore in one group half round wire was used which was etched followed by application of alloy primer.

It has also been said that materials more rigid than PMMA itself could improve the fracture strength.[32] This study shows that the mean flexural strength was highest in groups which were reinforced by half round wire treated with sandblasting and etching, with application of alloy primer (SW &EW). Samples reinforced with salinized woven roving e glass fibers (GF) also show comparatively better flexural strength. This variation may be because of the difference in flexural strength of reinforcing material. This can be correlated with earlier studies.[32]

In group C (SW) and D (EW) wires which were sandblasted, and acid etched showed the highest flexural strength. By comparing these groups there was no statistically significant difference which proves that sandblasting and etching produces micro irregularities on wire surface thus increasing surface area and the primer applied over it provided the chemical bond between acrylic resin and the wire. So, both the methods can be used effectively.

5. Limitations of the Study

The samples used in this investigation were created in line with ADA standard number 12, and the study was meticulously planned and executed. The following list outlines the limitations of the current investigation.

1. The repaired denture base is subjected to stresses of diverse intensities and directions within the mouth cavity. In this in vitro work, the identical circumstance could not be replicated.
2. In contrast to a fractured complete denture, which is often long, the length of the repair site investigated in this study is short. As a result, additional research is needed to assess repair strength under conditions that are more accurately representative of clinical settings.

The denture's curve in the oral cavity mimics the anatomical tissues' shapes. Due to the usage of rectangular acrylic strips in this investigation, the same curvature could not be replicated.

6. Conclusion

Within the limitations of this study following conclusions were drawn:

1. Specimens repaired with reinforcement increases the flexural strength
2. Reinforcement with salinized woven roving e glass fibers showed significant increase in flexural strength compared to unreinforced specimens.
3. Reinforcement with surface treated half round wires that are sandblasted and etched followed by application of alloy primer shows highly significant increase in flexural strength.
4. There was no statistical difference between the samples repaired with sandblasted wires and etched wires group.
5. With ease and convenience of etching the wires which do not require additional equipment like sandblaster makes it possible for wider application.

7. Source of Funding

None.

8. Conflict of Interest

None.

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