An *in vitro* study of the effect of design of repair surface on the transverse strength of repaired acrylic resin using autopolymerizing resin

H Mahajan, GS Chandu, SK Mishra

Department of Prosthodontics, Rishiraj College of Dental Sciences, Gandhinagar, Bhopal, Madhya Pradesh, India

Abstract

Statement of Problem: The fracture of complete denture is a common occurrence in the field of prosthodontics. Often if all other criteria are met such as good aesthetics, occlusion, and functionality; denture repair is acceptable. Once denture fractures, we would want the joint surface strength to be as good as original.

Purpose: The purpose of this study was to determine the effect of different repair surface design on the transverse strength of repaired acrylic denture resin.

Materials and Methods: Sixty specimens of heat-cured acrylic resin of dimension 65 mm × 20 mm × 2.5 mm were prepared using a special die. Transverse strength of 15 samples was calculated which serves as a control group. Three different types of joint surface contours were prepared each having 15 samples each as butt, round, and rabbet joint. Transverse strength of three joint contours was then compared with control group and also they were compared with each other and result was statistically analyzed with one-way analysis of variance (ANOVA) and Post-hoc ANOVA Tukey's HSD test at 5% level of significance. Z-test of proportion was also done for types of failures.

Result: Transverse strength of original specimen was higher than that of repaired specimens. Transverse strength of round joint was higher than the butt and rabbet joint.

Conclusion: Methods of repair have significant effect on strength of repaired denture. Round joint design of repair technique was far superior.

Key words: Autopolymerizing resin, rabbet joint, transverse strength

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Introduction

The fracture of acrylic resin prosthesis is a common occurrence, the prosthesis may fracture accidentally due to an impact outside the mouth or it may fracture while in service in the mouth. The later is generally the result of fatigue failure caused by repeated flexure over a period of time. This type of fracture occurs near or close to midline and it occurs more often in maxillary than in mandibular denture.[1]

The material most commonly used in the fabrication of any removable prosthesis and appliance is heat polymerizing resin. This material is preferred as denture base resin because of its physical and esthetic properties as well as the material availability, reasonable cost, and ease of manipulation.[2]

The repair of the fractured prosthesis can be accomplished using acrylic resins that are heat polymerized, autopolymerized, or light polymerized. Out of these the repair strength of heat polymerized resin is highest.[3] One of the principal factors which can vary the strength of a repaired joint is its design.[4]

Address for correspondence:
Dr. Harsh Mahajan, MDS,
Reader, Department of Maxillofacial Prosthodontics and Implantology, Rishiraj College of Dental Sciences and Research Centre, Bhopal, Madhya Pradesh - 462 036, India.
E-mail: drharshmahajan2004@yahoo.com

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In view of the confusion as to which is the best method of preparing the interface of the fractured surfaces[2,4,5] and in order to obtain strongest joint, this study was undertaken to investigate and evaluate three joint surface preparations that is rabbet, butt, and round joint.

Aim

The aim of the present study was to determine: (i) The effect of different repair surface design on the transverse strength of repaired acrylic denture resin. (ii) To find out the transverse strength of the heat-cured acrylic resin specimen. (iii) To evaluate transverse strength of butt, round, and rabbet joint after repair. (iv) To compare the transverse strength to the three designs with that of original specimen. (v) To evaluate the location of fracture.

Materials and Methods

Two stainless steel metal dies of dimension 65 mm × 20 mm × 20 mm were invested in dental plaster (Kaldent, Kalabhai Karson, Mumbai, India) in a dental flask. After setting of plaster the two halves of flask were separated and metal dies were removed from the flask. This gives us moulds for preparing a test specimen of heat-cured acrylic resin (DPI Heat Cure, Mumbai, India). Heat-cured acrylic resin was packed into mould cavity and benched-cured for 30 min. Then the flask was immersed in a thermostatically controlled acrylizer (Confident Dental Equipment Ltd, Bangalore, India) at 74°C for 2 h. Temperature of water bath was raised to 100°C and processing was carried out for 1 h. After the completion of curing cycle, the flask was removed from acrylizer and deflasking was done. The acrylic specimens were than retrieved finished and polished. Total numbers of 60 specimens were prepared.

Assessment of transverse strength

Transverse strength of the samples were tested by three-point bending test with the help of universal testing machine (Zwick, Materiaprufung 1445, Germany) at a cross head speed of 0.5 cm/min. Each sample was placed on a clamp; the distance between two clamps was 30 mm. A load was applied centrally to the specimen through 2.5 mm diameter hardened steel rod.

Preparation of different joint configurations

Three different types of joint surface contours were prepared each having 15 specimens each as follows:

Butt joint: A midline was marked on the specimen as shown in the Figure 1. Then the specimen was cut with the help of straight fissure carbide bur (018 and 010 HM21, Meisinger, Germany) using micromotor straight hand piece (Marathon, Saeyang, Korea).

Round joint: As shown in the Figure 2, two lines were marked in the specimen, between these two lines a round contour was marked and then with a help of straight fissure carbide bur specimen was cut.

Rabbet joint: For preparing this joint, a wax block (Pyrex, Roorkee, India) of dimension 65 mm × 20 mm × 2.5 mm was prepared and then the block was cut in the center with the help of carver (Vaishanav Surgical Co., Jalandhar, India). This gives us two wax blocks of equal length, then in each block 1.5 mm deep and 2 mm wide recess was created as shown in the Figure 3.

Then these two blocks were prepared in heat-cured resin by the conventional compression molding technique.

Repair method

After the preparation of joint configurations, the two halves of the specimen were placed in a stainless steel mould which was specially prepared for repairing the specimens [Figure 4]. The mould was prepared 2 mm bigger in size than the original length of the test specimen to provide bulk for self-cured resin [Figures 5 and 6].

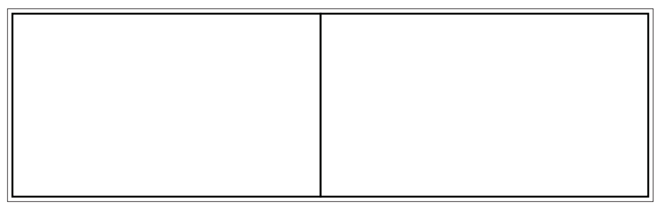

Figure 1: Butt joint

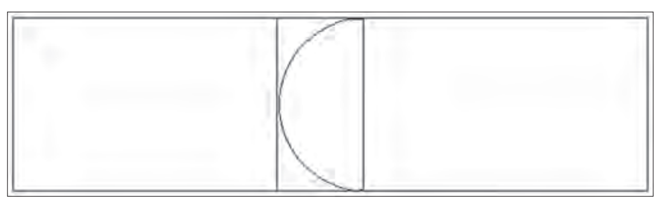

Figure 2: Round joint

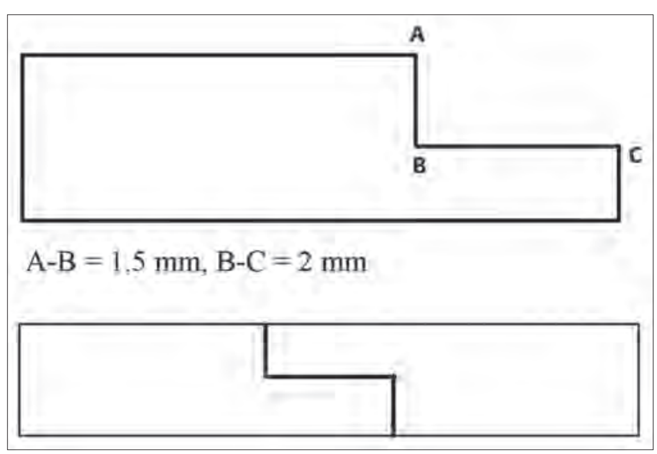

Figure 3: Rabbet joint

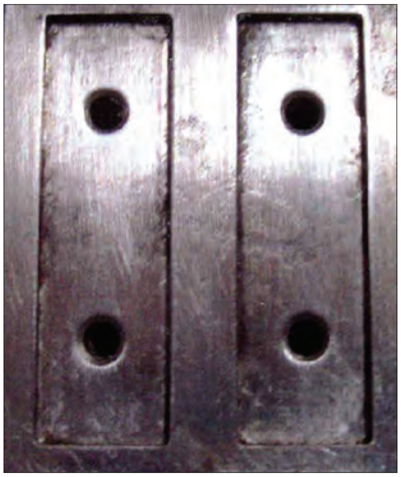

Figure 4: Stainless steel mould

Figure 5: Mould 2 mm bigger than the original specimen in round and butt joint

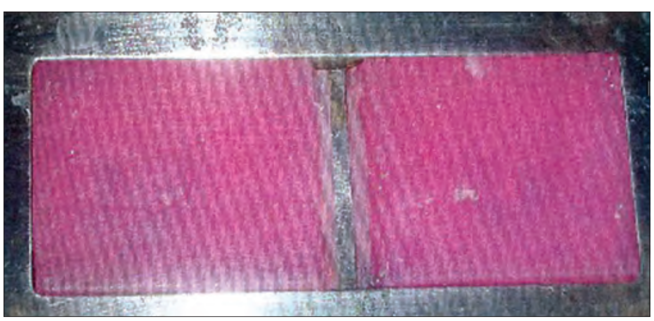

Figure 6: Mould 2 mm bigger than the original specimen in rabbet joint

Then self-cure monomer resin (DPI Self Cure, Mumbai, India) was placed in a gap using sprinkle-on technique.[6] After polymerization the specimens were finished and polished same as complete dentures.

Each specimen was stored in distilled water at room temperature for 48 h before testing. Then testing for transverse strength was carried out with the help of universal testing machine in same manner as described earlier. The result was statistically analyzed.

The statistical tests used were: One way analysis of variance (ANOVA) test, Post-hoc ANOVA Tukey's HSD test, and Z-test of proportion.

Results and Observation

The aim of the study was to evaluate the effect of butt, round, and rabbet joint surface contour on transverse strength of repaired acrylic resin. A total number of 60 test specimens of heat-cured acrylic resin were prepared.

The transverse strength of intact heat-cured samples (15 samples) was measured and served as control group.

The remaining 45 samples were divided into three groups depending upon joint surface contours as Group I: Butt joint, Group II: Round joint, and Group III: Rabbet joint (15 samples each).

Universal testing machine was used to evaluate transverse strength of intact and repaired acrylic resin samples.

Transverse strength was calculated by:
[$TS = 3\ PL/2\ bd^2$]
P = fractured load
L = distance between supports
b = specimen width
d = specimen thickness.

Comparison of transverse strength between control group and round, rabbet, and butt joint were done. Also, the transverse strength of the three joints surfaces were compared with each other and statically analyzed. Statistical analysis was done with one-way ANOVA test at 5% level of significance. The mean transverse strength and standard deviations (SD) of all groups is given in Table 1.

Statistical analysis showed that mean difference between all the groups were statistically significant. Among round, rabbet, and butt joint; lowest mean value of 14.86 MPa was recorded for Group 1 (butt joint). The highest mean value, 24.58 MPa was recorded for Group II (round joint) [Figure 7].

Since there was statistically significant mean difference between all the groups, the Post-hoc ANOVA Tukey's HSD test was done for pairwise comparison between each groups and they also showed a significant difference [Table 2]. When pairwise comparison was done, control group was best (mean = 46.97) followed by round (24.58), rabbet (17.57), and butt joint (14.86).

Table 3 showed predominant types of failure exhibited by the butt, round, and rabbet joint. Z-test of proportion was used for the comparison. Result showed that there was significant difference between round, rabbet, and butt joint. The round and rabbet joint demonstrated predominantly cohesive types of failure while the butt joint showed the adhesive types of failure.

Discussion

Fracture of complete denture irrespective of causative factor in majority of cases is an emergency, requiring prompt attention. Earliest repair of denture is main requirement of a patient. Repair of fractured denture with self-cured acrylic resin has long been popular as the time required for repair is less and is economical as well.[7]

Review of literature showed that various materials and techniques have been tried by different researchers for repairing fractured dentures.[3,4,8-13]

Berry and Funk have suggested the use of vitallium denture strengtheners to reduce or eliminate lower denture breakage.[4] Bowman and Manley[8] have confirmed that the carbon fiber reinforced polymethyl-methacrylate material was stronger by an order of magnitude than a conventional denture material. Beyli and von Fraunhofer[9] reported that butt joint for repair of fractured denture has been found to be inferior to inverse knife edge, round, and lap joint. Yazdanie and Mahmood[10] investigated the transverse strength of carbon fiber acrylic resin composite and confirmed that it is stronger and stiffer than unfilled acrylic resin. Gutteridge[11] tested the effect of short cut ultra-high modulus polyethylene fiber reinforcement on impact strength of acrylic resin and showed that there was an improvement in the strength up to a level of 3% fiber inclusion. Vallittu and Lassila[12] reported that specimens reinforced with glass fibers and metal wires demonstrated increased impact strength. George and D'Souza[13] evaluated the transverse strength of denture base material repaired by heat-cured and self-cured methods with and without surface chemical treatment using ethyl acetate. Both heat-cured samples treated with ethylacetate showed improved repaired strength. Minami *et al.*,[14] reported that specimens reinforced with 1.2 mm diameter stainless steel wire and Co-Cr-Ni wires significantly improved the flexural strength, whereas titanium wires and woven glass fibers were not affected for reinforcing denture base repair.

When choosing a repair technique other factors besides strength must be considered such as working time and the degree to which dimensional accuracy is maintained during repair.[15] When self-cured resins are used, repair can be accomplished faster because no denture flasking is needed. Additionally, the denture accuracy is maintained because during polymerization not enough heat is present to release stress. Heat-cured repairs require denture flasking and may distort the denture by releasing stress during processing.[16] The purpose of repair is to get at least equal or greater transverse strength then the original material.

In this study, self-cured resin was used as a repair material for repairing the test specimen because it is a quick procedure and it is cost-effective. In case of heat-cured resin repair, the patients have to remain without dentures for a longer time which is not acceptable by most of them.[7]

Table 1: One way ANOVA for transverse strength of different groups

Group	Mean	SD	*N*	F ratio	*P* value	Result
Control group	46.972	0.9408	15	3184.455	<0.0001	S
Butt joint	14.863	0.8034	15			
Round joint	24.579	1.4978	15			
Rabbet joint	17.573	0.7611	15			

There was significant variation between all four groups, $P<0.005$ was significant, ANOVA=Analysis of variance; SD=Standard deviation

Table 2: Pairwise comparisons via Tukey's HSD test

	B	C	D
A	<0.05	<0.05	<0.05
B		<0.05	<0.05
C			

HSD=1.101, $P<0.05$ was significant, A=Control group; B=Butt joint; C=Round joint; D=Rabbet joint

Table 3: Z-test of proportion for types of failure

Joint	Number of specimens	Adhesive failure	Cohesive failure	Z value	*P* value
Butt joint	15	13	2	8.3716	<0.0001
Round joint	15	4	11	4.0797	<0.0001
Rabbet joint	15	3	12	5.8095	<0.0001

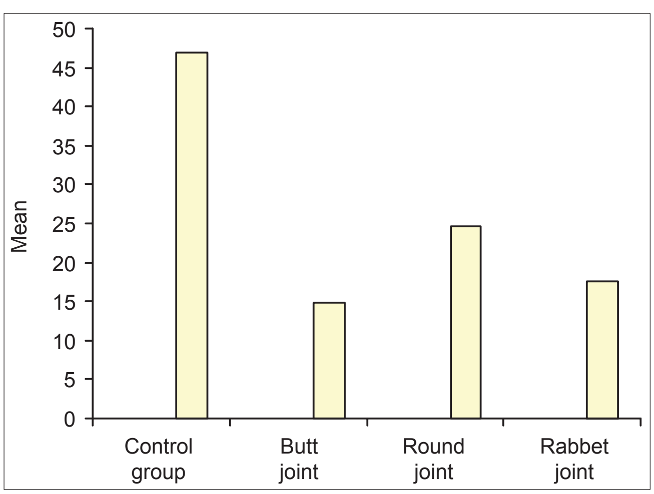

Figure 7: Mean bond strength of control group and butt, round, and rabbet joint

Universal testing machine was used to evaluate the transverse strength of intact and repair acrylic resin test specimen. Each specimen was subjected to the three point bending test at a crosshead speed of 0.5 cm/min.

The result of this study was in accordance with previous studies by Harrison and Stansbury,[17] Beyli,[9] Ward,[5] and Sharma *et al*.[2] Round joint was far superior to butt and rabbet joint, which supports the fact that a sharp angle surface promotes stress concentration. The amount of stress concentration is directly related to the degree and abruptness of surface changes. Geometry of round joint is such that it increases the interfacial bond area and shifts the interfacial stress pattern more towards a shear stress and away from the more damaging tensile stress exerted on the butt repair joint during flexure.[3]

The size of the gap between the two fractured segments should be 3 mm or less to minimize the bulk of repair material used. This will also reduce the color differences between denture base and repaired material. The lower bulk of repair material will also decrease the degree of polymerization shrinkage.[9]

For the butt joint, most failures occurred at the interface of original and repaired material (adhesive failure) [Figure 8]. For the round and rabbet joint the fracture was predominantly occurred through the repaired material (cohesive failure) [Figure 9].

This study does not simulate the clinical condition as repaired dentures are exposed to repeated mechanical stresses during mastication in the oral cavity. Also, the use of simple rectangular-shaped specimen rather than denture design contributes to the limitation of the present study.

Further studies are required to evaluate the strength of repaired dentures under more clinically simulated clinical conditions.

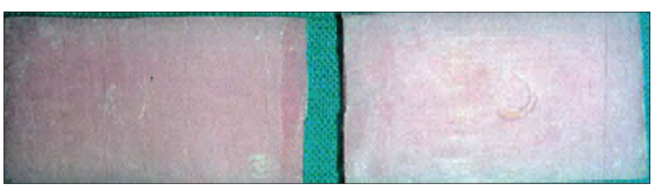

Figure 8: Adhesive failure

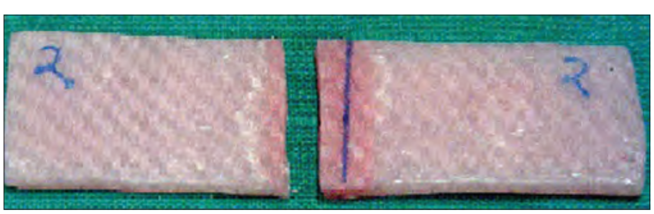

Figure 9: Cohesive failure

Conclusion

Within the limits of this study it can be concluded that the method of repair have significant effect on strength of repaired denture. The transverse strength of original specimen was far superior to repaired specimen. The transverse strength of round joint was higher than butt and rabbet joint. The round and rabbet joint demonstrated predominantly cohesive types of failure, while the butt joint showed the adhesive types of failure.

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