Role of Joint Designs and Surface Treatments on the Repair of Acrylic Resins- An Invitro Study

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ABSTRACT

Introduction: When a heat-polymerized acrylic denture base material is repaired, there is a need to strengthen the joint by modifying surfaces when quicker and economical repair is anticipated. Study aimed to evaluate the effect of different joint designs and chemical treatments on the heat-polymerized acrylic resin joint surfaces repaired with auto-polymerized acrylic resin.

Material and methods: This was the In-vitro study in which three metal dies of dimensions (65x10x2.5mm) were milled as per American Dental Association Specification no. 12 guidelines for denture base resins and sectioned exactly at the midline (31x10x3mm). The ends of each midsection were trimmed by 1.5mm into butt joint (Group I), 45- degree bevel joint (Group II) and rounded joint (Group III) creating a space of 3mm between sectioned dies for the placement of repair material. A total of 96 pairs of heat-polymerized acrylic resin samples were prepared using sectioned metal dies. Joint surfaces in each group were surface treated with three chemicals (Methyl methacrylate, Isopropanol & Phosphoric acid), repaired with autopolymerizing acrylic resin. Universal testing machine was used to find out the transverse strength of the repaired samples. One way Anova test and Tukey's Post hoc analysis was done in conjunction with ANOVA.

Results: Significant differences were found among the groups in terms of various joint surfaces (P<.001). All surface-treated specimens had higher transverse strength than controls.

Conclusions: The rounded joint design of heat-polymerized acrylic resin with Isopropanol surface treatment has the highest transverse strength and the control group has the lowest strength following repair. Surface treatment increases the strength of repaired joint to two folds. Rounded joint decreases the stress concentration and crack propagation.

Keywords: Denture Repair, Butt Joint, Rounded Joint, Bevel Joint, Heat-polymerized, Auto-polymerizing, Surface Treatment

INTRODUCTION

Polymethyl methacrylate resins (PMMA) have been widely used as a denture base material for more than 50 years in the dental market.[1] In spite of the advancement of materials and reinforcement of denture base resin with various materials, the fracture of PMMA denture bases is a common clinical occurrence.[2] Repair of fractured denture bases is considered a quicker option than fabricating a newer prosthesis provided it has the same bond strength as the parent resin, maintain the dimensional stability and should have a good color match.

Out of the repair materials, heat polymerized resin is considered to have the highest repair strength however use of auto-polymerizing resin is considered to be easy, quick and approximates the repair strength of heat cure resin.[3,4] The bond strength can be enhanced with variations in the joint design of the joint surfaces in addition to the surface treatments. This study is done to evaluate the repair strength of different joint designs i.e. butt joint, bevel joint and rounded joint after surface treatments with Methylmethacrylate monomer, Isopropanol and Phosphoric acid. The objective was to compare the repair strength of joint surfaces of acrylic resin with & without surface treatments.

MATERIAL AND METHODS

To carry out the study, three metal dies of dimensions (65x10x2.5mm) were milled by standard tool manufacturer as per American Dental Association Specification no. 12 guidelines for denture base resins. These three dies were sectioned exactly at the midline (31x10x2.5mm) and the ends of each midsection were trimmed by 1.5mm into butt joint (Group I), 45- degree bevel joint (Group II) and rounded joint (Group III) creating a space of 3mm between sectioned dies for the placement of repair material (Figure 1).

The sectioned metal dies were used for the fabrication of heat cure samples. The mold spaces were created in Varsity Dental Flasks No.7 (Jabbar & Company, Aligarh, Uttar Pradesh and India) by investing metal dies in Dental Stone (Kalabhai Karson Pvt Ltd, Mumbai, India) and were packed

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with heat-cure acrylic resin (Travelon Hi - Dentsply Pvt Ltd, Noida, India) using a mixture of monomer and polymer in the ratio of 21 g (32 cc)/10 ml by weight. Curing was done using Digital Acryliser (Unident Instruments Private Ltd, New Delhi) according to the manufacturer's instructions. All the prepared 96 pairs of heat cure samples were grouped to Group I, Group II and Group III of 32 each and were again divided into four subgroups based on surface treatments on the joint regions. Each Sub group has eight samples.

Subgroup A: Control group without any joint surface treatments

Subgroup B: Joint surface treated with Methylmethacrylate monomer (Rapid Repair- Dentsply Pvt Ltd, Noida, India) for 120 sec.

Subgroup C: Joint surface treated with Isopropanol (Cero™, Cero Chemicals, Navi Mumbai) for 5 sec.

Subgroup D: Joint surface treated with Phosphoric acid (D-Tech Dental Technologies, Pune, India) for 30 sec.

A standard metal mould (78x70x10mm) was fabricated for placing the heat cure samples during sample repair. It consists of a bottom flat plate with guiding pins, middle compartment consists of two (65x10x2.5mm) rectangular mould spaces, into which sectioned and trimmed metal dies fits exactly (Figure 2) and the flat top plate has guiding holes. The heat cure samples of similar joint surfaces after surface treatments were placed onto the standard stainless steel mould with the bottom & middle compartment (Figure 3). Samples were then repaired with autopolymerizing acrylic resin using 'sprinkle on' technique. A total of 96 samples have been repaired in the above-mentioned process and stored in distilled water for 7 days at 37 degrees centigrade to simulate intra oral condition.

To find the transverse strength, 3-point bending test was done with a perpendicular load at 20 mm distance with a crosshead speed of 5 mm/min at the centre of autopolymerizing repair resin using Universal testing machine (Instron India Pvt. Ltd. Chennai, Tamil Nadu).

Transverse strength =

$$\frac{3(\text{load at fracture} \times \text{distance between end beams})}{2(\text{width of specimen} \times \text{thickness of specimen}^2)}$$

STATISTICAL ANALYSIS

The obtained data was entered into Microsoft excel 2007 and subjected to statistical analysis using statistical package for social sciences (SPSS Version 20.0). The collected data were summarized using Means and Standard deviations. One way Anova test was done and Tukey's Post hoc analysis were done in conjunction with ANOVA.

RESULTS

Values of transverse strength summarized using mean and standard deviation for three groups i.e. butt joint (Group I), 45- degree bevel joint (Group II) and rounded joint (Group III) designs and with their Subgroups representing surface treatments of the joint surfaces (Control, Methylmethacrylate monomer, Isopropanol & Phosphoric acid) are presented in Table 1. The study has shown that joint surface chemical

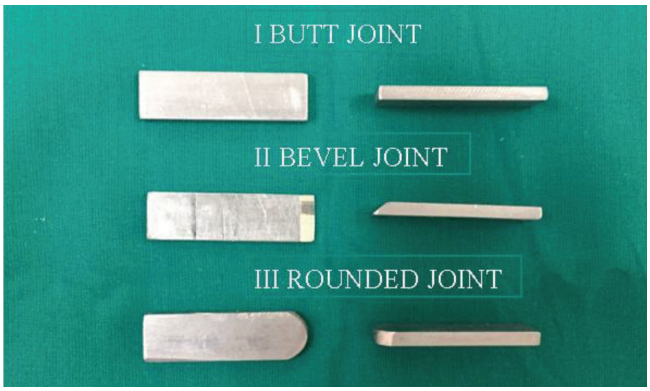


Figure-1: Sectioned metal dies with three different joint designs

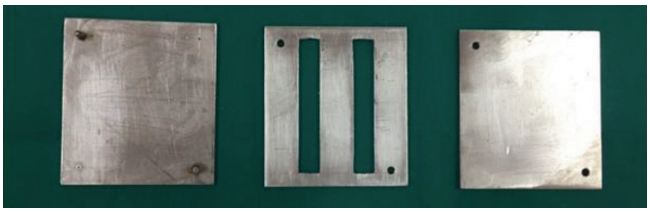


Figure-2: Stainless steel moulds with upper, middle and lower compartments

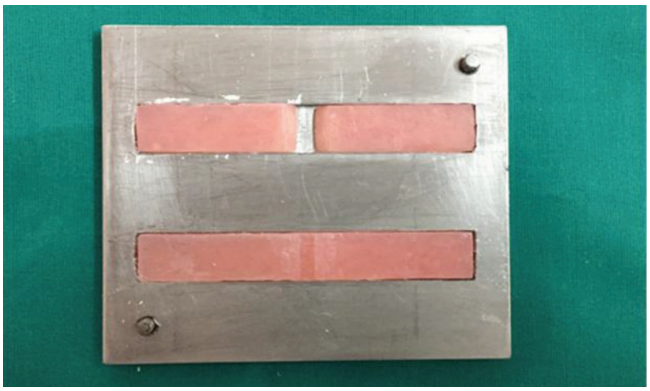


Figure-3: Heat cure sample repaired positioned in Stainless steel moulds with sprinkle-on technique

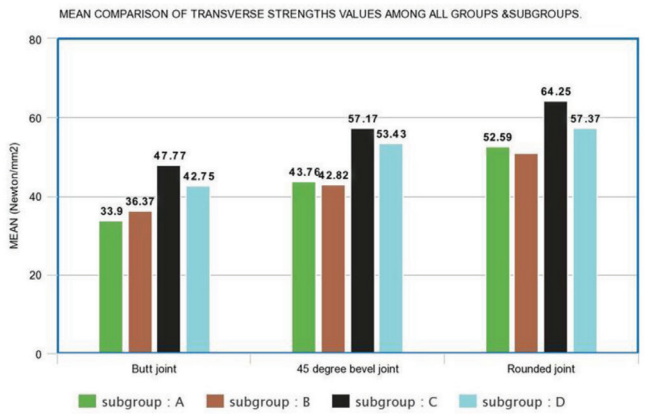


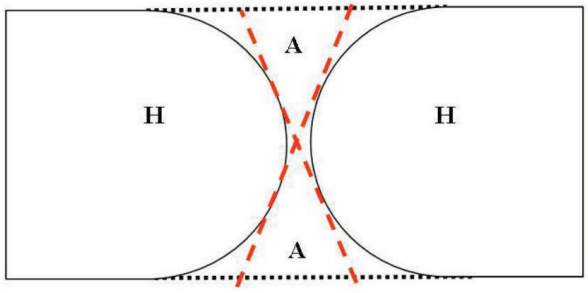
Figure-4: Graph showing mean comparison of transverse strength of all groups; butt joint design (Group I), 450 bevel joint design (Group II) & rounded joint design (Group III) & Subgroups representing various surface treatments after repair.

Mean Comparison of Transverse Strengths Values Among All Groups & Sub-Groups (One Way ANOVA Test)												
Groups	**Subgroup A (Control)**			**Subgroup B (Methylmethacrylate)**			**SubgroupC (Isopropanol)**			**Subgroup D (Phosphoric acid)**		
	Mean	**SD**	**P (value)**	**Mean**	**SD**	**P (value)**	**Mean**	**SD**	**P (value)**	**Mean**	**SD**	**P (value)**
Group I (Butt Joint)	33.90	3.2	0.00*	36.3	1.55	0.00*	47.77	1.85	0.00*	42.75	2.57	0.00*
GroupII (45^0 bevel Joint)	43.76	2.7		42.8	1.76		57.17	2.86		53.43	2.01	
Group III (Rounded Joint)	52.59	3.9		51.0	5.44		64.25	4.67		57.37	1.81	
*Statistically significant if P<0.0												

Table-1: Demonstrates the overall mean comparison of transverse strength values of all the repaired samples with & without surface treatments.

Mean Comparisons of Transverse Strengths Between Groups In Butt Joint, 45^0 Bevel Joint & Rounded Joint Designs (Newton/mm^2) (Tukey Post Hoc Test)									
Groups	**Butt joint (Group I)**			**45^0 bevel joint (Group II)**			**Rounded joint (Group III)**		
	Mean	**SD**	**Difference Mean±SD (p value)**	**Mean**	**SD**	**Difference Mean±SD (p value)**	**Mean**	**SD**	**Difference Mean±SD (p value)**
Sub Group A (Control)	33.90	3.24	2.47±1.69 (0.189)	43.76	2.74	0.94±0.98 (0.858)	52.59	3.96	1.55±1.48 (0.881)
Sub Group B (Methylmethacryate)	36.37	1.55		42.82	1.76		51.04	5.44	
Sub Group A (Control)	33.90	3.24	13.87±1.39 (0.000*)	43.76	2.74	13.41±0.12 (0.000*)	52.59	3.96	11.66±0.71 (0.000*)
Sub Group C (Isopropanol)	47.77	1.85		57.17	2.86		64.25	4.67	
Sub Group A (Control)	33.90	3.24	8.85±0.67 (0.000*)	43.76	2.74	9.67±0.73 (0.000*)	52.59	3.96	4.78±2.15 (0.127)
Sub Group D (Phosphoric acid)	42.75	2.57		53.43	2.01		57.37	1.81	
* Statistically significant if P<0.05									

Table-2: Demonstrates mean comparisons of transverse strengths between groups in butt joint, 450 bevel joint and rounded joint designs



H— Heat cure denture base resin , A— Autopolymerizing repair resin

Figure-5: Schematic representation of rounded joint surface with hour glass design of the repaired resin showing double inclined surfaces and doubling of repair area.

treatment with Methylmethacrylate monomer, Isopropanol & Phosphoric acid increased the transverse strength of repaired samples. One-way ANOVA revealed that there was a statistically significant difference in mean of transverse strengths of the three groups and subgroups. It shows that subgroup C, the joint surface treated with Isopropanalol has the highest transverse strength values in their respective groups. Also among the entire three joint designs, the rounded joint design showed superior transverse strength values (Figure 4). Tukey's Post Hoc test shows no statistical significance between Subgroup A (Control) & Subgroup B (Methylmethacryate) on the mean of transverse strengths in all the Groups (Butt Joint, 45 degrees bevel and rounded joint designs) (Table 2). Whereas significant difference was noticed between the Subgroup A (Control) and Subgroups C (Isopropanol) & D (Phosphoric acid) on mean transverse strengths in all the Groups except between Subgroup A (Control) and D (Phosphoric acid) with rounded joint design.

DISCUSSION

Most extensively used material for fabrication of denture bases are acrylic resins inspite of the advent of many newer materials lately. But susceptibility to fracture is one of its major drawbacks, which causes inconvenience and embarrassment to the dentist and the patient. Most of the patients demand repair of their existing dentures rather than the construction

of new dentures.[5] Also dimensional accuracy and color match are some of the requisites for a satisfactory repair.[6] There are various factors which are found to affect dental repairs such as the type of material and its reinforcement, joint design and joint surface treatment.[5]Approximately 85% of the original strength of heat cure resin is exhibited when used to repair a denture base; however, dimensional changes are more in heat cure resin when compared to autopolymerizing acrylic resin. There was a considerable change in contour after the heat cure dentures were repaired by the heat curing method, but relatively no changes resulted from the self-curing repairs.[7] Agarwal et al[8] conducted a study to evaluate the transverse strength of different repair materials wherein autopolymerizing acrylic resin exhibited the repair strength similar to those of conventional heat and microwave polymerized acrylic resin but these are costlier and requires special equipment and thus difficult to be used in the routine clinical scenario. Another study conducted by Venkat et al.[9] evaluated the mechanical properties and dimensional stability of denture base repair resin. Heat cure polymethyl methacrylate with polyethylene fiber was affirmed as a material of choice for denture repair based on their study. However, it is also suggested that reinforcement of autopolymerizing repair resin with additional materials can be utilized for denture repair as the use of heat cure resin with polythene fibers in the clinical scenarios is tedious and might increase the cost of the treatment. Repair of dentures with autopolymerizing resins was quicker and less costlier. They showed superior adaptation than denture repaired with heat curing resins. But it was found to have about 50% strength of heat cure resin.[10] It can be enhanced by altering the joint design and joint surface pretreatment.

Out of all joint designs, the round end joint has shown the highest transverse bond strength compared with all different variables. The results of the present study are coinciding with previous studies conducted by Harrison et al[6] in 1970 and John E ward et al[11] in 1992 which were carried out without any joint surface treatments. John E Ward et al evaluated the mean transverse strength of denture bases with butt joint, bevel joint and rounded joint. The highest transverse strength was for the rounded joint with 22.04 units. However, in the present study, the values ranged from 51.04 to 57.37 units. This two-fold increase of the transverse strength can be attributed to the various surface treatments of the denture base.

In addition to the surface treatment, the rounded joints have no sharp edges or margins thus decreasing the stress concentration of crack propagation. It has an added advantage of having an increased surface area by forming an hourglass pattern with doubled surface area of the repair area mimicking two 45 degrees beveled inclined planes as in Group II (Figure 5).

The 45-degree bevel joint also aids in increased strength when compared to the butt joint. It is preferred more in the clinical scenario as it's easy to prepare and finish. There is a shift of the mode of fracture from a weak, adhesive interfacial fracture for the butt repair to a stronger cohesive fracture of the repair material in the 45-degree bevel and rounded repairs. The geometry of 45-degree bevel and rounded repairs increases the interfacial bond area and shifts the interfacial stress pattern more toward a shear stress and away from the more damaging tensile stress exerted on the butt repair during flexure.[11]

A similar study by Mahajan et al[3] on the butt, rounded and rabbet joint designs without any surface treatment showed that rounded joints have higher transverse strength than other joints. The rounded design mentioned in their study was rounded on one joint surface and flat on the other surface whereas in the present study it has rounded on both the joint surfaces increasing the surface area.

In the present study use of Methylacrylate has improved the transverse strengths of the repaired samples when compared with the control group. Rounded joint design configuration showed the highest transverse strength value (51.04) when compared to 45^0 bevel joint (42.82) and butt joint (36.37) after Methylmethacrylate surface treatment.

Among all the joint surface treatments, samples repaired after treatment with Isoproponal showed the highest transverse strength values in their respective groups. The mean transverse strength values after Isopropanol treatment are butt joint (47.77), 45^0 bevel joint (57.17) and rounded joint (64.25) shown significant p values. The results of this current study are in correlation with the previous studies done by Suad Al Nakash. [12]

Some of the other previous studies Naveen S Yadav[13] & Y. Sinasi Sarac[14] have shown a variable increase in the transverse strength values of the repaired samples after chemical surface treatments like acetone, methylene chloride, ethyl acetate & dichloromethane. On contrary, results of both Belyi and VonFrunhofer (1980) [15] and Grajower and Goultschin (1984) [16] are not matching with the current study, where they stated that the application of a surface pretreatment did not affect transverse strength. Other chemical agents can also be used for the surface modification of the denture base as well like ethyl acetate and methylene chloride accorging to Shreya et al. They concluded that both these chemical agents improved the transverse strength of the repaired heat cure denture base with methylene chloride subjecting to have superior results.[17]

Limitations of the study

This in-vitro study evaluated the effect of different joint surfaces and surface pretreatment on transverse strength of repaired acrylic denture base samples, but

- It did not simulate the clinical condition, where repeated mechanical stresses occur during mastication and longer periods of salivary contact and repeated thermal cycling.
- The use of simple rectangular shape specimen rather than a complex denture design did not reveal exact clinical standard.
- Contamination by saliva may affect the bond between repair material and denture base resin, especially during chair-side repair. It is therefore questionable whether the results of this study can be applied to clinical practice.

CONCLUSION

Within the limitations of this study, it can be stated that among all the mechanical joint surface configurations, round end joint design has shown highest transverse bond strength & the next highest was with 45° bevel joint samples with a significant difference. All the repaired samples showed increased transverse bond strength after chemical surface treatment when compared with the respective control groups. Among the three chemical surface treatments (Methylmethacrylate, Isopropanol and Phosphoric acid) used in the study, rounded joint samples repaired after Isopropanol joint surface treatment showed the highest transverse strength.

REFERENCES

1. Rodney D. Phoenix, Michael A. Mansueto, Neal A. Ackerman and Robert E. Jones. Evaluation of Mechanical and Thermal properties of commonly used Denture base resins. J Prosthodont 2004; 13: 17-27
2. Rosangelo Seiko Seo, Karin Hermana Neppelenbroek and Neudenir Ariolli Filho. Factors affecting the strength of denture repairs. J Prosthodont 2007; 16:302-310.
3. H Mahajan, GS Chandu, SK Mishra. An invitro study of the effect of design of repair surfaceon the transverse strength of repaired acrylic resin using autoplymerizing resin. Nigerian Journal of Clinical Practice 2014;1:38-42
4. Gregory L Polyzois, Dr Dent, Andreas G Andreopoulos and Panagiotis E Lagouvardos. Acrylic resin denture repair with adhesive resin and metal wires effect on strength parameters. J Prosthet Dent 1996; 75: 381-387.
5. Mustafa Gundogdu, Zeynep Yesil Duymus & Murat Alkurt. Effect of surface treatments on the bond strength of soft denture lining materials to an acrylic resin denture base. J Prosthet Dent 2014; 112:964-71.
6. Naveen S Yadav, Shilpi Khare, Sunil Kumar Mishra, Rajesh Vyas, Harsh Mahajan, Rajkiran Chitumalla. In-vitro Evaluation of Transverse Strength of Repaired Heat Cured Denture Base Resins without Surface Treatment and with Chemical and Mechanical Surface Treatment. Journal of International Oral Health 2015; 7:89-92.
7. Peyton FA, Anthony DH. Evaluation of dentures processed by different techniques. J Prosthet Dent 1963; 13: 269-82.
8. Manisha Agarwal, Ajay Nayak, R.B. Hallikerimath. A study to evaluate the transverse strength of repaired acrylic denture resins with conventional heat cured, autopolymerizing and microwave – cured resins: An in vitro study. J Indian Prosthodont Soc 2008; 8:1.
9. R. Venkat, N. Gopichnader, M. Vasantakumar. Comprehensive analysis of repair/reinforcement materials for polymethyl methacrylate denture bases: Mechanical and dimensional stability characteristics. J Indian Prosthodont Soc 2013;4: 439-449
10. Stanford JW, Burns CL, Paffenbarger GC. Self-curing resins for repairing dentures: some physical properties. J Am Dent Assoc 1955; 51:307-15.
11. John E. Ward, Peter C. Moon, Robert A. Levine and Carol L. Behrendt. Effect of repair surface design, repair material and processing method on the transverse strength of repaired acrylic denture. J Prosthet Dent 1992; 67: 815-820.
12. Suad Al Nakash. The Influence of Different Chemical Surface Treatment on Transverse Strength of Repaired Heat Cure Acrylic Resins. Journal of Al Rafidain University 2013; 31:93 -115.
13. Naveen S Yadav, Shilpi Khare, Sunil Kumar Mishra, Rajesh Vyas, Harsh Mahajan, Rajkiran Chitumalla. In-vitro Evaluation of Transverse Strength of Repaired Heat Cured Denture Base Resins without Surface Treatment and with Chemical and Mechanical Surface Treatment. Journal of International Oral Health 2015; 7:89-92.
14. Y. Sinasi Sarac, Duygu Sarac, Tolga Kulunk and Safak Kulunk- The effect of chemical surface treatments of different denture base resins on the shear bond strength of denture repair. J Prosthet Dent 2005; 94:259-66.
15. Carroll CE, von Fraunhofer JA. Wire reinforcement of acrylic resin prostheses. J Prosthet Dent 1984 Nov; 52:639-41.
16. Grajower R, GoultschinJ. The transverse strength of acrylic resin strips and of repaired acrylic samples. J Oral Rehabil 1984;11:237-47.
17. Colvenkar Shreya Siddesh, Meena A. Aras. In vitro evaluation of transverse strength of repaired heat cured denture base resins with and without surface chemical treatment. J Indian Prosthodont Soc 2008; 8:2.

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