Comparison on the Transverse Strength of Heat Cure Polymethylmethacrylate Denture Base Resin Repaired with Different Surface Treatments and Surface Design Modifications

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Abstract

Introduction: Fracture of denture being most common clinical complain in daily Prosthodontic practice, results in great inconvenience to patient and humiliation to Prosthodontist. A satisfactory repair should be cost-effective, simple to perform, match the original color and not cause distortion to the existing denture.

Objective: The aim of the present study is to investigate the effect of different surface treatments and surface design modifications on the transverse strength of repaired heat cure polymethylmethacrylate denture base resin

Materials and Methods: A total of 135 rectangular specimens measuring 65 x 10 x 2.5 mm were made from heat cure PMMA resin using standardized mould. They were further divided into following 5 groups with 27 specimens in each group with simple random sampling method. Group A: control, Group B: 45° bevel of the edge, Group C: rounded contour of the edge, Group D: dichloromethane application at the edge and Group E: sandblasting of the edge. The repair index was fabricated with poly vinyl siloxane (putty). The specimens in each sample group were sectioned in the center to form 2 parts with approximately 3mm gap in between them. The sectioned surface of each sample group was modified according to their group specification and repaired using autopolymerizing acrylic resin. All the repaired specimens were tested for transverse strength in universal testing machine by subjecting them to 3-point bend test and the value at which the fracture of specimen occurred were noted. Data were analyzed with one-way ANOVA for multiple group comparisons followed by Tukey post hoc for group comparison ($p<0.05$).

Results: Transverse strength of original specimen was higher than that of repaired specimen. Transverse strength of specimen repaired with surface design modification with rounded contour of the edge was higher than chemical and mechanical treatment and 45°bevel of the edge

Conclusion: Within the limits of the study, irrespective of the method of repair, the transverse strength of surface design modification with rounded contour of the edges was significantly higher than the group repaired with surface design modification 45° bevel of the edge, chemical treatment with dichloromethane application at the edge and mechanical treatment by sandblasting of the edge.

Key words: Acrylic resin; Joint contours; Dichloromethane; Sandblasting; Repair; Transverse strength

Introduction

Wide variety of denture base materials is used in the fabrication of partial or complete dentures. Historically leather, gold, wood, ivory were the materials used for fabricating primitive forms of denture. Vulcanite, as denture base material had also been widely used for many decades but the

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outbreak of World War II and the subsequent shortage of the raw material and placed acrylic resin in the forefront. The main drawback of the material is its low strength and dimensional instability which leads to inaccuracy of fit.[1]

However, the fracture of polymethylmethacrylate denture bases is a common clinical occurrence and often involve either impact or fatigue failure.[2-5] Regardless of the reason for fracture or the method for repair, the ultimate goal of denture repair is to restore original strength of the denture and avoid further fracture.[6] Denture repair material and design should have adequate strength, dimensional stability, good color match, easily and quickly performable and relatively inexpensive. The repair of a denture base can be performed using several materials but the choice of material depends on the working time, the strength to be obtained with the repair material and the degree of dimensional stability maintained during and after repair.[7]

The repair strength of heat-polymerized materials ranges from 75% to 80% of the original material, whereas microwave-polymerized acrylic resins have shown repair strengths of 93% to 106% of the original acrylic resin. Although the conventional and microwave-polymerized materials demonstrate superior strength, these materials require a significant amount of working time due to necessary packing and flasking procedures and also present the added risk of denture distortion by heat.[8,9]

With these materials having advantages and disadvantages, the use of autopolymerizing resin is the most popular material of repair.[9] The repair strength of autopolymerizing acrylic resins have been shown to be approximately 60% to 65% of the original material, which is lower than strengths achieved with heat-polymerized acrylic resins. However, the strength of autopolymerizing resin as a repair material can be improved with various surface treatments and modifications such as by changing either the joint surface contours, the processing methods, optimizing the distance between repaired sites, by using surface treatment, or reinforcing materials such as metal wires, polymethylmethacrylate, aramide or nylon fibers.[7,8,10] Mechanical modifications such as sandblasting improve the strength of repaired surface by increasing the surface area and mechanical retention to promote adhesion.[11-14]

Successful denture repair also depends upon the phenomenon of adhesion which ensures that a good bond exists between the repair material and the broken surfaces to be joined. Surface treating the acrylic denture base with Organic solvents such as ethyl acetate, methylene chloride, dichloromethane significantly improve the bond strength between acrylic denture base and repair resin. Bond strength of denture repair has been commonly evaluated by transverse strength test which can be conducted by 3-point loading and more closely represents the type of loading applied to a denture in the mouth.[15]

Hence, the aim of the present study is to investigate the effect of different surface treatments and surface design modifications on the transverse strength of repaired heat cure polymethylmethacrylate denture base resin.

Materials and Methods

This study was conducted in the Department of Prosthodontics and Maxillofacial Prosthetics, People's Dental College and Hospital, Kathmandu, Nepal. A total of 135 test specimens measuring 65 x 10 x 2.5 mm were made from heat cure polymethylmethacrylate (PMMA) resin using standardized metal mould. (Fig 1) They were further divided into 5 groups (n = 27) with simple random sampling (lottery method) depending on different surface treatments and design modifications.

A. **Preparation of repair index:**

The standardized master metal specimen (65x10x2.5) mm was invested in putty consistency polyvinylsiloxane to prepare a repair index. After the polyvinyl siloxane is set, the metal specimen was retrieved. All the acrylic samples were adjusted to fit into the mould. (Fig 2, 3)

B. **Preparation of repair sample:**

The specimens in each sample group were sectioned in the center to form 2 parts with 3 mm gap in between them and were grouped as:_

Group A specimens: No surface treatment and surface design modification were done.

Group B specimens: Edge of both halves of the joining specimen was made 45° bevel with the help of a carbide bur.

Group C specimens: Edge of both halves of the joining specimen was made round with the help of a carbide bur.

Group D specimens: Edge of both halves of the joining specimen that were facing each other in the repair index were treated with dichloromethane for 60 seconds and then dried.

Groups E specimens: Edge of both halves of the joining specimen that were facing each other in the repair index were sandblasted with 50 µ aluminum oxide particles at controlled distance of 10 mm for 30 seconds under 5 kg/cm^2 of pressure.

After surface design modification and treatment, the specimens were placed in the repair index. Autopolymerizing acrylic resin was mixed in a clear container following manufacturers instruction and packed in the gap between the specimens. There auto polymerizing acrylic resin was allowed to cure. After being repaired, all the specimens were carefully restored to their original dimensions using sand paper and stored in 37°C distilled water for 48 hours before the test.

All repaired specimens were tested for transverse strength in a Universal Testing Machine (UTM). (Fig 4) For testing, the specimens were placed between the two holding clamps of Universal Testing Machine and locked and subjected to 3-point loading test. Then the load was set to zero and increased progressively at the rate of 5 mm/min until the specimen was broken. The reading in machine until the fracture occurred was noted which was used to calculate the transverse strength by means of specimen's cross section area according to following equation:

$S=3WL/2bd^2$

Where:

S=Transverse strength

W= Load at fracture

L= distance between supporting wedges (50 mm)

b= width of specimen (10 mm)

d= thickness of specimen (2.5 mm)

Data were entered on SPSS version 20. Since the data were of continuous type, parametric test was used for analysis. Mean and Standard Deviation (SD) were calculated. Since, data were normally distributed, one-way Analysis of Variance (ANOVA) using F statistic of data were carried out for testing significance of the differences in the mean values for multiple group comparisons, followed by Tukey post hoc test for group wise comparisons. All results were considered statistically significant if $P<0.05$.

Results

The maximum transverse strength value was observed for the group repaired with surface design modification as shown in Table 1. One-way ANOVA TEST ($F= 366.02$, $P<0.001$) with standard error of 3.9154 showed that mean difference between all possible paired combinations among all groups were statistically highly significant as shown in Table 2.

Multiple group comparison using Post Hoc Tukey Test yielded a significant difference of mean transverse strength between different groups as shown in Table 3. Group repaired with surface design modification by rounded contour of the edge had significantly higher transverse strength value than surface design modification by 45° bevel of the edge [Mean difference (46.28) MPa], chemical treatment with Dichloromethane application at the edge [Mean difference (42.18) MPa] and mechanical treatment by sandblasting of the edges [Mean difference (28.29) MPa].

Group repaired with mechanical treatment by sandblasting of the edges had significantly lower transverse strength than rounded contour of the edge [Mean difference (28.29) MPa] but had significantly higher transverse strength values than 45° bevel of the edge [Mean difference (17.98) MPa], chemical treatment with dichloromethane application at the edge [Mean difference (13.88) MPa].

Figure 1: Master metal specimen

Fig 2: Putty (polyvinyl siloxane) index

Fig 3: Repair Index

Fig 4: 3-point loading test in UTM

Table 1: Mean Transverse strength and Standard Deviation values for each group

Groups		N	Mean (Mpa)	SD
A	Control	27	163.322222	19.5958263
B	**45° bevel of the edge**	27	34.937037	8.1845609
C	Rounded contour of the edge	27	81.222222	18.3471090
D	Dichloromethane application	27	39.037037	8.9196476
E	Sandblasting	27	52.925926	12.9480498
Total		**135**	**74.288889**	**49.6191821**

Table 2: One-way ANOVA

Transverse strength	Sum of squares	Df	Mean Square	F	Sig.
Between Groups	303011.362	4	75752.841	366.022	.000
Within Groups	26905.111	130	206.962		

Significant difference at α=0.05

Table 3: Post Hoc Tukey Test

Tukey HSD	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
	Control	45° Bevel of the edge	128.3851852*	3.9154243	.000
		Rounded contour of the edge	82.1000000*	3.9154243	.000
		Dichlormethane application	124.2851852*	3.9154243	.000
		Sandlasting	110.3962963*	3.9154243	.000

Significant difference at α=0.05

Discussion

The fracture of acrylic dentures is a long-standing problem and a common clinical occurrence in Prosthodontic practice.[1] Hargreaves AS did a survey on prevalence of fractured dentures and reported that 68% of dentures had broken within 3 years of their fabrication.[16] Regardless of the reason for fracture or the method for repair, the ultimate goal of denture repair is to have adequate repair strength in order to avoid further fracture.[2,3]

Stanford JW found that the average strength of specimens repaired with heat curing resin was approximately 80% of the original strength of the denture base resins while that of self-curing resin was approximately 57-60%.[17] Skinner reported the greater values of bond strength of heat cured resins over self-cured resins, as repair materials can be attributed to higher degree of polymerization and lower residual monomer content of heat polymerized resin.[18] Also the temperature rise during the polymerization of self-cure resins appears to have direct bearing on the amount of residual monomer in the polymerized material.[17]

Photoelastic analysis of flexural strength of the fragments of a broken denture shows an increase in internal stress which is due to the breaking of molecular bonds at the points of fracture. Alteration of molecular forces within each fragment results in distortion of the fractured sections, which often causes difficulty in reassembling the broken fragments.[8,9] To gain optimum strength for repairs, it is essential that a good bond exists between these two types of acrylic resin. The fundamental difference between the heat processed denture base resin and autopolymerizing acrylic resin is the method by which benzoyl peroxide is decomposed to yield free radicals. Generally, the conversion achieved using chemically autopolymerizing acrylic resin is not as complete as that achieved using heat activated systems. Chemically activated resin exhibits physical properties that are somewhat inferior to those of heat processed denture base resin and displays lower transverse strength. Therefore attempts have been made to improve the mechanical properties of repaired sites by changing either joint surface contour, processing methods, optimizing the distance between repair sites and by surface treatments or reinforcing materials.

Heat cure polymethylmethacrylate test specimen with dimensions of 65±0.3×10±0.03×2.5±0.03mm (length, width, thickness respectively) were prepared for transverse strength test, according to the Specification No.12 of the American Dental Association (ADA) which was used as a guideline for preparing the specimens.[19]

Transverse strength was selected as the unit of comparison because it is most commonly reported for these types of studies in dental literatures. Transverse strength also known as flexural strength or modulus of rupture is a collective measurement of tensile, compressive and shear stresses. This strength is important because it reflects the rigidity of the material, which in turn is important for the integrity of the supporting ridge and tissues, along with the fitting accuracy of the denture.[20]

The size of the gap between the two fractured segments was 3 mm to standardize 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. [4,5]

In the present study the specimen repaired with rounded joint contour was superior to other groups supports the general principle that sharp angled surfaces promote stress concentration and amount of stress concentration is directly related to the degree and abruptness of surface change. Since residual stress is produced and sharp-angled surfaces concentrate the stresses, when repairing a fractured acrylic resin prosthesis, one should attempt to prevent recurrent structural failure by distributing these stresses as evenly as possible by preparing a joint with rounded interface surfaces. The result of this study was in accordance with previous studies by Harrison WM and Stansbury BE[12], Beyli MS[4], Ward JE[21] and Sharma A et al.[6] Harrison WM and Stansburry BE [12] and Ward JE[21] observed that the transverse strength of the butt joint was significantly less than that of the rounded or 45◦ bevel joints but the transverse strength of the round and 45◦ bevel joints was statistically significant.

Mahajan H[3] have demonstrated significantly higher transverse strength specimen repaired with of round joint contour which was in consistent with the finding of the present study. Lin C et al.[11] also recommended the rounded joint as the best choice. The rounded joint is nonlinear and has a greater contact area (78.5 mm^2) with the denture base than either the butt (50 mm^2) or 45◦ bevel joint (72 mm^2) designs.[11] On the other hand, the 45◦ bevel joint is preferred clinically, since it is easier to prepare and finish a beveled joint than a rounded joint. Alumina air-abrasion is utilized to roughen the repair surface of the denture base to increase the area of bond contributing to micromechanical retention and eliminating substances which adhere to the surface of the repair region. Shimazu H[23] found that air abrasion with 50 µm alumina followed by application of dichloromethane improved the bond between repaired surface because of synergistic effect on morphologic changes by means of dichloromethane and increasing of surface area due to air abrasion. In contrast with the present study, Savendra G[24] in a study compared different surface modifications and found sandblasting better. Azad Ali[25] in their study found significant decrease in bond strength after sand blasting.

Attempts to improve the bond strength of repair material to denture base resins by means of chemical treatment of repair surfaces were advocated by several investigations. Anusavice reported that such surface treatment with chemical etchants as chloroform, acetone, methylmethaacrylate, methylene chloride, ethylacetate caused superficial crack propagation as well as formation of numerous pits approximately 2 mm in diameter which enhance the mechanical retention between treated surface and repaired resin.[26]

Dichloromethane, is an organic and nonpolymerizable solvent, which swells the surface and permits a diffusion of the polymerizable material. The strength of the bond depends upon the degree of penetration of the solvent and the strength of the interwoven polymer network formed thereafter. Dichloromethane preparation can create surface pores and channels approximately 1 µm in diameter on a conventional acrylic resin and these channels tend to interconnect frequently. This morphological change also occurs when dichloromethane is applied to heat processed denture base resin. Prepolymerizing PMMA pearls present in the denture base resin should allow diffusion of the dichloromethane solvent. According to Shen C et al, wetting the denture base resin surface with chloroform for 5 seconds creates a cleaner and more efficient site for bonding, increasing the strength of denture repairs. However, chloroform was identified as a noxious compound with a carcinogenic potential and precautions are necessary to avoid inhaling chloroform vapor during surface treatment.[27]

Conclusion

At present no repair material meets the ideal requisites as optimal transverse strength, ease of manipulation, cost and inconspicuousness. Repair with self-cure acrylic resin has been the most popular as it is simple, quick and needs no heating equipment, but it lacks adequate bond strength and rigidity. As fabrication of new denture is an expensive and time consuming procedure, clinical knowledge about the choice of material and method of repair is important till a definite prosthesis can be fabricated for the patient.

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