ORIGINAL RESEARCH

Influence of Thermocycling and Surface Treatments on the Flexural Strength of Denture Base Resin: An *In Vitro* Study

Harsimran Kaur[1], Aditi Nanda[2], Kusum Datta[3]

Abstract

Aim: The purpose of this study was to evaluate the flexural strength of heat polymerized denture base resin after thermocycling and different surface treatments done prior to repair or relining.

Materials and methods: In this *in vitro* study, 80 specimens were made with heat-polymerized denture base resin and thermocycled (500 cycles between 5 and 55 °C). The specimens were divided in four groups based on different types of surface treatment: group I (control group: without surface treatment), group II (chloroform for 30 seconds), group III [methyl methacrylate (MMA) for 180 seconds], and group IV (dichloromethane for 15 seconds). The flexural strength was assessed using a Universal testing machine with three-point bending test. The obtained data were subjected to statistical analysis using one-way ANOVA and *post-hoc* tests.

Results: The values of average flexural strength of denture base resin measured were as follows: group I: 111.1 MPa, group II: 86.9 MPa, group III: 73.1 MPa, and group IV: 78.8 MPa. Groups II and IV possessed superior flexural strength than group III. The maximum values were observed with the control group.

Conclusion: The flexural strength of heat-polymerized denture base resin gets affected by different surface treatments done prior to relining procedures. Lowest flexural strength was obtained when treated with MMA monomer for 180 seconds as compared to the other etchants used.

Clinical significance: Prior to denture repair procedures, operators must choose the chemical surface treatment judiciously. It should not affect the mechanical properties such as flexural strength of denture base resins. Reduction in flexural strength of polymethyl methacrylate (PMMA) denture base can predispose the prosthesis to deteriorated performance when in function.

Keywords: Acrylic resin, Denture repair, Flexural strength, Poly(methyl methacrylate).

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Introduction

The prerequisite for denture base polymers includes adequate mechanical properties to prevent denture fracture associated with cyclic deformation or impact on to a hard surface.[1,2] Denture bases can fracture or crack while in use, which is very inconvenient for both patient and the dentist.[3] The fracture can happen because of improper occlusion, poorly fitting denture base, stress on the denture base when in clinical use, and mishaps occurring with the complete denture outside the mouth.[4] Hence, the flexure strength test, which simulates the load that affects maxillary complete dentures *in situ*, has been used to evaluate the flexural strength of denture materials.[5,6] Denture bases are regularly exposed to heat stress in the oral cavity, especially when drinking hot or cold beverages. These thermal changes can affect the sorption of water, which is a process based on thermal changes. Denture acrylic's bending strength may be decreased by the plasticizing effects of absorbed water molecules that enter the polymer network between the chains.[7]

The method to rectify the problem of fractured denture base is the repair procedure, which is considered as a necessity of complete dentures.[8] The choice of repair methods or materials for denture bases depends on a number of variables, including the transverse strength, the amount of time required for the procedure, and the degree of dimensional precision of the repair material.[9,10] However, due to the limited strength of the repaired segments, new fractures can develop in bases that have been managed for fracture.[3]

According to some authors,[4,8,10] "the success of denture repair relies on the phenomenon of adhesion" and surface treatments, such as application of methyl methacrylate, chloroform, methylene chloride, and acetone. They can be utilized to strengthen the bond between the denture foundation and repair material.[9–11] Denture cleansers can also significantly affect the flexural strength of nano-ZrO_2 modified denture base materials and thus should be used cautiously.[12] These chemical agents work by changing the morphology and chemical properties of the surface of denture base allowing the repair material to diffuse into it and promote better adhesion.[13] The region of the foundation prosthesis treated by chemical agents once altered can act as a zone of weakness which when subjected to an impact can induce failure in the prosthesis. Looking into the drastic sequelae of surface treatment, it hence

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becomes important to study the effect of these treatments on the flexural strength of denture base resin, which forms the prosthesis itself. The aim of the *in vitro* study was to assess the influence of surface treatment with various chemicals (done before the repair or relining) on flexure strength of heat polymerized resin, which forms the foundation of the prosthesis. The null hypothesis of the study is that no statistical difference exists between the flexural strength of untreated and the treated heat polymerized resin groups.

Materials and Methods

Setting and Design

The study conducted here was an *in vitro* type of study. It was carried out in the Department of Prosthodontics for a period of 1 year from 2019 to 2020 to evaluate the effect of thermocycling and surface treatment on flexural strength of denture base resin.

Sampling Criteria

The sample size was calculated with a sample size calculator (Sample Size Determination in Health Studies, World Health Organization, power at 90%) based on the previous studies. The study protocol was conducted in line with the principles of the Helsinki Declaration, including all revisions, and with the approval of the Government Dental college, Amritsar, Punjab, Board of ethics.

Sample Preparation

Eighty specimens were produced with acrylic resin that has been heat polymerized. The specimens were divided into four groups depending upon the surface treatment received, as listed in Table 1 [control (no treatment), chloroform (SolvChem), dichloromethane (RANKEM), and methyl methacrylate (Pyrax)]. Metal die was made with the rectangular cavity with the decided dimensions of 65 × 10 × 3.3 mm (Fig. 1). The heat-polymerized acrylic resin was used according to the instructions mentioned by manufacturers, and the inner surface of the metal pattern was lined with a thin layer of petroleum jelly before packing it with PMMA resin. Rectangular blocks of heat-cured PMMA resin were prepared by curing the material in dough stage in the brass die. Sheet of polyethylene was put over the acrylic resin before the flask was closed to be pressed in a hydraulic press for trial closure. The packing pressure of 17 bars was applied to remove the resin excess as flash. Then, the flask was kept under 42.5 bars of pressure for half an hour. Further, the flask was immersed in water at 74°C for 9 hours in a polymerizing unit (long polymerization cycle). The flask was subjected to bench cooling before opening. The specimens were then gently removed from the metal template, and any extra acrylic resin was trimmed off using tungsten steel burs and a handpiece operating at a low speed. The specimens were finished using 600-grit silicon carbide paper (Fig. 2).

Table 1: Different experimental groups

Group	*Treatment*
Group I (G1)	Without surface treatment
Group II (G2)	Wetting with chloroform for 30s
Group III (G3)	Wetting with methyl methacrylate monomer for 180s
Group IV (G4)	Wetting with dichloromethane for 15s

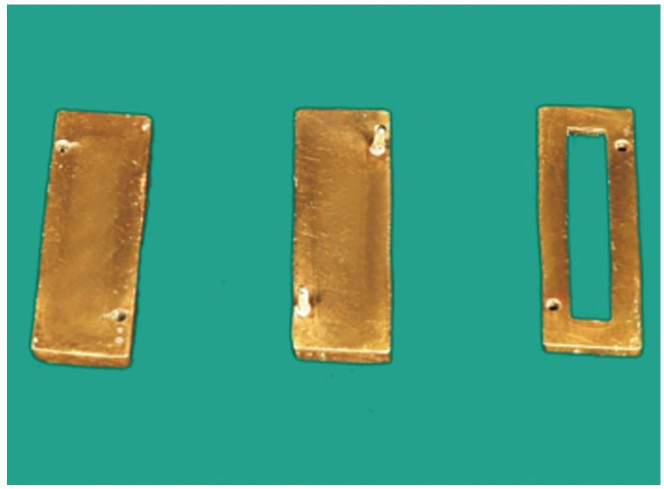

Fig. 1: Three parts of the brass die

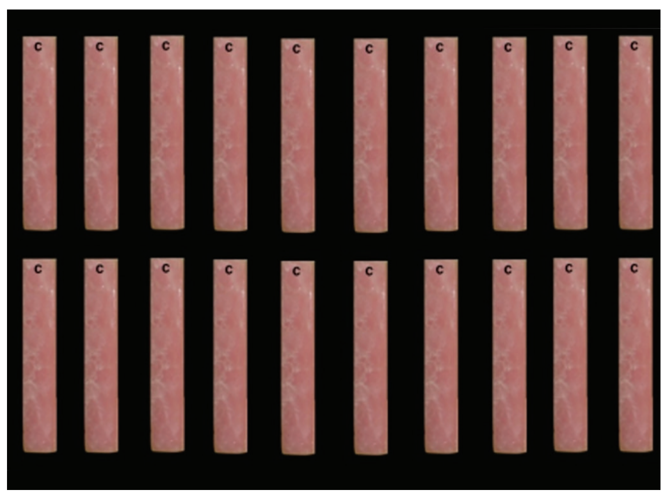

Fig. 2: Specimens of denture base resin

Thermocycling and Surface Treatment

Specimens were thermocycled (500 cycles between 5 and 55 °C) for 30 seconds in each water bath. Then, the specimens were subjected to surface treatment, wherein group I received no surface treatment and acted as a control, group II was treated with chloroform for 30 seconds, group III with methyl methacrylate for 180 seconds, and group IV with dichloromethane for 15 seconds.

Testing Procedure

The three-point bending test was carried out to assess the flexural strength of specimens using a Llyod's universal testing machine with a 100 kgf load cell with a cross-head speed of 5 mm/min. The maximum force applied was utilized to determine the specimen's flexural strength after the load was engaged until it fractured each specimen in accordance to ISO-20795-1, which is as follows:

$$S = \frac{3WL}{2bd^2}$$

where

S = Flexural strength
W = Peak load (in kg)
L = Distance between supports (50 mm)

b = Width of the specimen in cm (10 mm)
d = Specimen thickness (3.3 mm)

The SI units were used to represent the data of flexural strength, and its being converted to MPa by multiplying with 9.8. The data thus obtained were subjected to statistical analysis by applying the quantitative analysis using various parametric tests.

Statistical Analysis

The obtained data were evaluated with ANOVA and Bonferroni *post hoc* test using SPSS 19 (IBM Corporation, Armonk, NY, USA) at the significance level, $p = 0.05$. The power of the study was set at 80%.

Results

The detailed data of flexural strength of each specimen were statistically analyzed. The distribution of mean ± SD of flexural strength (Mpa) in control, 30 seconds of chloroform treatment, 180 seconds of MMA monomer treatment, and 15 seconds of dichloromethane treatment is 111.10 ± 13.74246, 86.9000 ± 3.40046, 73.1700 ± 2.02331, and 78.7700 ± 3.93140, respectively (Table 2 and Fig. 3). On applying one-way ANOVA, we found the mean of strength in all groups is significant $p = 0.000$ ($p < 0.05$) (Table 3). *Post hoc* Bonferroni adjustments were applied for multiple comparisons of flexural strength in groups (Table 4).

Discussion

Flexural strength is a crucial indicator of a denture base material's capacity to bear functional masticatory stresses as well as high-impact forces in case of accidental drops. The three-point flexural strength test is helpful in comparing denture base materials as it mimics the type of stress that is delivered to denture base resin during mastication.[14] Flexural strength testing has been done in the present study to investigate the effect of chemical surface treatments on the strength of the denture base resin. The PMMA specimens repaired with heat polymerized resins resulted in a significantly higher load to fracture compared to auto and light polymerized resin.[15] Thermocycling is an effective way to simulate the clinical conditions. It is performed aiming to create thermal strains at the bonding interface by thermal changes in water baths between 5 and 55°C. It has been observed that the absorption of water into the resin is influenced by the polarity of the PMMA molecules and diffusion of water molecules into the interstitial spaces between polymer chains. The increase in temperature may lead to water molecules to penetrate more rapidly into the denture base material.[9] Water diffused into polymer acts as a plasticizer, enabling the chains to cross each other more effortlessly when under load; thus, mechanical properties of the polymers may get influenced. It was assessed that the chemical treatment and thermocycling dramatically reduced the flexural strength of denture base resin in comparison to the control group.[16] Temperature changes (thermal cycling) significantly reduced the hardness and flexural strength and increased surface roughness but did not affect the impact strength. The decrease was more for MMA

Table 2: Distribution of mean ± SD of flexural strength (Mpa) in different groups

Groups	*Mean ± std. deviation*	*Std. error*	*95% Confidence interval for mean*		*Minimum*	*Maximum*	*p-value*
			Lower bound	*Upper bound*			
Control	111.10 ± 13.74246	3.07291	104.6633	117.5267	89.40	138.90	
30s of chloroform treatment	86.9000 ± 3.40046	0.76037	85.3085	88.4915	82.70	96.70	0.001*
180s of MMA monomer treatment	73.1700 ± 2.02331	0.45243	72.2231	74.1169	70.80	80.50	
15s of dichloromethane treatment	78.7700 ± 3.93140	0.87909	76.9300	80.6100	72.60	86.20	

*Significant $p < 0.05$

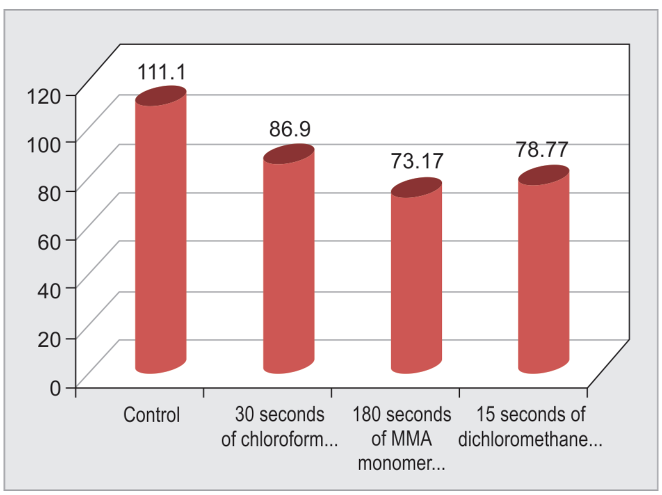

Fig. 3: Distribution of mean of flexural strength (Mpa) in different groups

Table 3: One-way ANOVA

	ANOVA				
	Flexural strength (Mpa)				
	Sum of squares	*Df*	*Mean square*	*F*	*Sig.*
Between groups	16772.895	3	5590.965	101.669	0.001
Within groups	4179.393	76	54.992		
Total	20952.289	79			

Table 4: *Post hoc* Bonferroni tests: flexural strength (Mpa)

Comparison group	*Mean difference (I-J)*	*Std. error*	*p-value*	*95% Confidence interval* *Lower bound*	*Upper bound*
Control					
30s of chloroform treatment	24.19500*	2.34504	0.001*	17.8421	30.5479
180s of MMA monomer treatment	37.92500*	2.34504	0.001*	31.5721	44.2779
15s of dichloromethane treatment	32.32500*	2.34504	0.001*	25.9721	38.6779
30s of chloroform treatment					
180s of MMA monomer treatment	13.73000*	2.34504	0.001*	7.3771	20.0829
15s of dichloromethane treatment	8.13000*	2.34504	0.005*	1.7771	14.4829
180s of MMA monomer treatment					
15s of dichloromethane treatment	–5.60000	2.34504	0.117**	–11.9529	0.7529

*significant; **highly significant

(73.17 MPa) and least for chloroform (86.9 MPa). The reduction in flexural strength of denture base resin can be attributed to dissolution of denture base resin caused by chemical surface treatments. The outcome of reduced strength of denture base resin may lead to issues associated with denture base flexure during use and during impact. According to this study, the highest flexural strength was obtained with the control group and lowest was obtained with MMA monomer treatment for 180 seconds. The mean values of measured flexural strength of denture base resin in the descending order were as follows: control group (111.1 MPa), chloroform for 30 seconds (86.9 MPa), dichloromethane for 15 seconds (78.8 MPa), and MMA monomer for 180 seconds (73.1 MPa).

According to Sarac et al., the mean values of flexural strength of denture base resin were 75.7, 72.5, 71.5, and 70.6 MPa with control group, methylene chloride treatment for 15 seconds, acetone treatment for 30 seconds, and MMA monomer treatment for 180 seconds, respectively, which is in agreement with the present study.[17] These findings were similar with the flexural strength conclusions of the study by Can et al. that monomer treatment decreased both of the flexural modulus and impact strength of the denture base resin.[18] The null hypothesis is rejected for the study as we can conclude that there is a significant effect of various surface treatments on the flexural strength of denture base resins. The limitation of the present study design is the absence of a true clinical condition, and the tested specimens did not physically simulate an actual denture. It is necessary to emphasize that fracture of denture bases can occur during function as result of fatigue failure. Hence, some methodologies, such as dynamic fatigue studies in water or artificial saliva, can be used to approach the clinical situation. In addition, future clinical investigations with patients should be made to evaluate the behavior of repairs in denture bases.

Clinical significance of the study is that during the repair of denture base resin, operators must choose the least harmful chemical surface treatment method prior to repair. Previous studies have indicated various methods, which promote repair. However, hitherto no study has shown the effect of chemical surface treatment on inherent denture base resin. Unless the inherent denture base resin persists to stay strong enough, the purpose of repair is defeated and one can encounter repeated fracture of denture base resin (weakened by chemical treatment).

Conclusion

Within the limits of this *in vitro* study, it can be concluded the lowest flexural strength of poly(methyl methacrylate) was obtained when it is thermocycled and treated with MMA monomer for 180 seconds as compared to the other chemicals. A reduction in flexural strength of PMMA denture base can predispose it to deteriorated performance every time the denture undergoes cyclic functional deformation, which can be frustrating for geriatric patients.

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