Influence of Different Reline Materials and Processing Methods on Flexural Strength of Denture Base Material

SUMMARY

Background/Aim: Relining is defined as the procedure used to resurface the tissue side of a denture with new base material, thus producing an accurate adaptation is provided at the denture foundation area. During mastication, relined dentures have to withstand masticatory forces to prevent fracture. The aim of this study was to evaluate the flexural strength of acrylic resin denture base relined with different methods and materials. **Material and Methods:** Fourteen experimental groups and one control group were determined to consider different reline materials and processing methods. Acrylic resin specimens were prepared with the dimensions of 65x 10x 1.5 mm and reline materials (1.5 mm thickness) were placed on acrylic resins. Reline material was not used in control group specimens. Flexural strength values of relined and control specimens were measured with three-point bending test at a speed of 5 mm/min. Data were analyzed with using one way Anova and Student t tests. **Results:** The highest flexural strength values were shown in control group (86.51 ± 1.08 MPa). There were significant differences among relined specimens ($p < 0.05$). For the relined specimens, the highest flexural strength values were found in the relined specimens with denture base material (77.90 ± 1.93 MPa), and the lowest values were found in relined with autopolymerize acrylic material (59.81 ± 1.50 MPa). **Conclusions:** Relining of the heat cure denture base material significantly decreases the flexural strength for all processing methods and materials.

Key words: Denture Base, Flexural Strength, Relining

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Introduction

Polymethyl methacrylate (PMMA) materials are most commonly used to fabricate of removable prosthetic restorations. Easy manipulation, low water absorption, compatibility and aesthetic appearance are the important advantages of PMMA^{1,2}. Also, these polymers enable to relining of denture base to improve the fitting in case of bone resorption³.

Residual ridge resorption, which is an inevitable process, occurs after tooth extraction especially first three months and the amount of resorption slows down in time⁴. Besides, some local and systemic factors such as anatomic, metabolic, psychosocial and mechanical

can affect the process^{4,6}. As a result of residual ridge resorption, function, stability and retention of removable prosthesis are impaired by decrease of fitting⁴. Relining procedure may be required to improve the adaptation to the supporting tissues of complete, partial and overdenture prosthesis⁷⁻⁹.

The strength of relined dentures is affected by denture base polymer, relining material and their adhesion at the interface¹⁰. Due to weak bonding, bacterial invasion, staining, delamination may occur between the denture base and the lining material, as well as decreased mechanical strength^{9,11}. The composition and processing technique are determinants of mechanical properties of the relining materials^{12,13}. Generally, relining materials

contain methyl methacrylate (MMA), which is similar to PMMA denture base, to increase the bond strength¹⁴.

Several methods can be performed to analyse the strength of relined denture materials such as impact strength and flexural strength^{10,14,15}. During mastication, denture base is exposed to flexural stresses and it was observed that the flexural stresses can cause the formation of a crack, which results fracture of denture base¹⁶. Therefore, the flexural strength of materials is important parameter for clinical success of prosthetic restorations.

The aim of this in vitro study was to evaluate the flexural strength of acrylic resin denture base, which was relined with different materials and processing technics.

The null hypothesis was that denture relining materials has no effect on the flexural strength of relined denture base.

Material and Methods

The brand and code names, manufacturers, compositions of the materials used in this study are shown in Table 1. Fourteen groups were determined according to the reline material and processing methods, and a control group were formed. Specimens were prepared according to International Standards Organization Specification No.20795-1:2013 for the denture base polymers¹⁷.

Table 1. Materials used in this study

Brand	Code	Manufacturer	Feature	Powder	Liquid
Meliodent	M	Heraeus Kulzer GmbH D-63450 Hanau, Germany	Rapid Heat Polymerised Acrylic Resin	Methyl methacrylate	Methyl methacrylate Glycol dimethacrylate
				Ethyl hexyl acrylate	Dimethyl P-toluidine
				N-octyl methacrylate	
Meliodent Rapid Repair	MO	Heraeus Kulzer GmbH D-63450 Hanau, Germany	Autopolymerised Acrylic Resin	Methyl methacrylate	Methyl methacrylate
				N-octyl methacrylate	Glycol dimethacrylate
				Benzoin peroxide	Dimethyl P-toluidine
Acron-S	A	Howmedica Austenal Dental Products,	Heat Polymerised Acrylic Resin	Methyl methacrylate	Ethylene dimethacrylate
Lucitone 199	L	Dentsply York Division, Usa	Heat Polymerised,		
			High-Impact Acrylic Resin	Methyl methacrylate	Ethylene dimethacrylate
Triad Reline Material	T	Dentsply York Division, Usa	Visible Light-Polymerized Paste-Type Resin	Methacrylate copolymers, a polyfunctional monomer such as urethane dimethacrylate and silica filler	
Acron-Mc	AM	Gc-Dental Ind. Corp. Tokyo-Japan	Microwave-Polymerised Acrylic Resin	Polymethylmethacrylate-ethylacrylate	Methyl methacrylate
				copolymer	N-dimethyl P-toluidine

Preparation of Bulk Denture Resin Specimens

Six denture resin specimens were prepared with dimensions of 65×10×3 mm for control group and 84 denture resin specimens were prepared with dimensions of 65×10×1.5 mm for relining procedures. The cast molds were made by using brass blocks. Heat polymerized polymethyl methacrylate material was placed into the cast mold and were polymerized according to the manufacturer's recommendation. All of the specimens was smoothed with 600-grit SiC paper and the dimensions of specimens were measured with a caliper (Mitutoyo Sul, Americana, Suzano, SP, Brazil). Specimens to be relined of one surface, and control specimens were stored in distilled water at 37°C for 48 h to ensure saturation.

Preparation of Relined Specimens

Eighty-four denture resin rectangular specimens (65×10×1.5 mm) were placed in the lower portion of cast molds, which were prepared previously with dimensions of 65×10×3 mm. Fourteen experimental subgroups were determined according to processing methods and relining materials (n= 6). The remaining 1.5 mm thickness of cast molds was filled with different relining materials. Processing methods of the materials and group codes used in this study are listed in Table 2. Heat-polymerization (for the water bath processing group) was performed in a thermostatically controlled water bath (Kavo EWL 5501, Kavo Electrotechnisches Werk GmbH, Germany). Microwave-polymerization was performed in a fiber-reinforced plastic flask (FRP, H.K. type, G.C. Dental Indust. Corp. Tokyo, Japan) and polymerization was completed in a 2450-MHz microwave oven with a rotating turntable (Vestel Goldstar ER 535 MT, Manisa, Turkey) with 1 cycle. Visible light cure polymerization was completed in Triad 2000 VLC Unit (Dentsply York Division, US). Eventually, relined specimens were made with using 1.5 mm thickness relining resin on 1.5 mm thickness denture base resin. The all relined specimens were measured with caliper and were immersed in 37°C distilled water for 48 h prior to the flexural test.

Flexural Strength Tests

The flexural strength test was conducted according to ISO Specification No. 20795-1:2013 for the denture base polymers. Specimens were subjected to three-point bending test on a support of 50 mm on a Universal test machine (Instron Model No 1195, Instron Ltd. England) with a cross-head speed of 5 mm/min until fracture occurred to detected flexural strength. For flexural strength tests, the denture base resin surface was placed facedown for each of the composite specimens, imitating

Table 2. Abbreviations of Control Group (M) and Relined Test Groups according to the Polymerization Methods

Group name	Polymerization cycles
M	Under hydrolic pressure for 15 min then 20 min at 70 °C, then 22 min in water bath 100°C
MM1	Under hydrolic pressure for 15 min then 20 min at 70°C, then 22 min in water bath 100°C
MM2	Under hydraulic pressure for 15 min, then 9 h in water bath at 70°C
MM3	15 min under hydraulic pressure, then microwave-polymerization for 3 min at 500 W
MA1	Under hydraulic pressure for 15 min, then 1 h at 70°C, 1h 100°C in water bath
MA2	Under hydraulic pressure for 15 min, then 9 h in water bath at 70°C
MA3	15 min under hydraulic pressure, then microwave-polymerization for 3 min at 500 W
ML1	Under hydraulic pressure for 15 min, then 90 min at 72°C, then 30 min 100°C in water bath
ML2	Under hydraulic pressure for 15 min, then 9 h in water bath at 70°C
ML3	15 min under hydraulic pressure, then microwave-polymerization for 3 min at 500 W
MO1	Autopolymerization for 14 min under hydraulic pressure, then 12 h under clamp
MO2	15 min under hydraulic pressure, then microwave-polymerization for 3 min at 500 W
MT1	Surface treatment with Triad bonding agent, then light activation for 10 minute
MT2	Chemical surface treatment with monomer, then light activation for 10 minute
MAM	15 min under hydraulic pressure, then microwave-polymerization for 3 min at 500 W

the clinical situation where the relining material is mostly under compression.

The flexural strength was calculated using the following formula: $S = 3FL/2bh^2$;

S; the flexural strength of specimen (MPa)

F; maximum load applied on the specimen at the time of fracture (N)

L; the distance between two supports (mm)

h; the height of specimen measured immediately prior to water storage (mm)

b; the width of specimen measured immediately prior to water storage (mm).

Statistical Analysis

The statistical analysis was performed by SPSS for windows version 18.0. Normality of the data was determined by the Shapiro-Wilk test. The homogeneity of variances was carried out by using Levene's test. The data were analyzed by one-way ANOVA. $\alpha = 0.05$. Student t post-hoc test was used to compare the mean of flexural strength of each relined group.

Results

The mean and standard deviation values of flexural strength of control and relined groups are presented in Table 3. Statistical analysis revealed that intact denture base control specimens showed significantly higher flexural strength (86.51 ± 1.08 MPa) than those of all relined groups (63.15 ± 2.60 MPa to 77.90 ± 1.93 MPa) ($p < 0.001$). Also, there were statistically significant differences in flexural strength among specimens relined with different materials and methods ($p < 0.05$) as shown Table 3.

Table 3. Mean and standard deviation (SD) of flexural strengths (MPa) of control and relined test groups

Group	Flexural Strength (MPa)
	Mean $\pm$ SD
M	86.51 ± 1.08 a
MM1	77.90 ± 1.93 b
MM2	68.33 ± 1.93 c,d,f
MM3	71.53 ± 2.23 c,d,f
MA1	70.44 ± 1.66 c,d,f
MA2	67.47 ± 1.80 c,d,f
MA3	73.16 ± 5.08 b,f
ML1	68.82 ± 2.20 c,f
ML2	64.08 ± 4.23 c,f
ML3	63.15 ± 2.60 c,f
MO1	59.81 ± 1.50 e
MO2	67.98 ± 3.91 f
MT1	63.73 ± 3.64 c,e
MT2	65.75 ± 0.97 c,e
MAM	72.20 ± 4.78 b

Means followed by different letters represent statistical significance ($p < 0.05$) Means with superscript of the same letter indicate no significant difference ($p \geq 0.05$)

Discussion

This study demonstrated the effect of different reline materials and different polymerization types on the flexural strength of heat cured PMMA. All relined specimens showed lower flexural strength values than non-relined control specimens. Therefore, the null hypothesis that the denture relining materials have no effect on flexural strength of relined dentures was rejected.

The adaptation of removable dentures on the oral tissues is an important factor to obtain stability, retention and support. Residual ridge resorption is natural process, which is resulted loss of adaptation of denture¹⁸. Therefore, the relining procedure often requires to provide the fit of the removable dentures. However, relining procedure may decrease the flexural strength of denture base and it is considered as negative effect¹⁹. In this study, it was observed that the control group have significantly highest flexural strength mean value.

The function of reline materials relates with their characteristics, mechanical properties and adhesion quality at interface¹⁰. Some studies were stated that autopolymerized reline resins decrease the flexural strength of heat polymerized denture base material^{12,13}. In accordance with this result, in this study, the lowest flexural strength was detected in autopolymerized reline specimens (59.81 MPa). Autopolymerized reline acrylic resins content a higher degree of residual monomer because chemical activator achieves a low degree of conversion compared to heat activation^{7,20}. Consequently, this residual monomer, which acts as a plasticizer, impairs the mechanical properties of denture base^{7,21}. Different polymerization techniques may be applied to increase the degree of conversion and decrease content of residual monomer such as immersion in hot water and microwave irradiation^{7,22-24}.

Microwave irradiation, causes positively movement effect on acrylic resin monomer and internal heat is induced with this movement. The heat is scattered more homogenously and also residual monomer content and porosity are decreased^{25,26}. Moreover, the polymerization is completed in short time period. Thus, microwave irradiation provides to increase the strength of acrylic resin. In this study, the strength of special microwave acrylic resin (MAM) was the strongest relined group except that were relined using the same material (MM1) as the denture base itself and there was no significant difference between them. It was observed that microwave polymerization significantly increased the flexural strength values of autopolymerized acrylic resin and the polymerization of microwave energy of autopolymerized resin can be advantageous for the durability of the relining process due to short polymerization time and low oven power. Minimize level of residual monomer and toxicity reduction may be obtained with using microwave irradiation on heat polymerized acrylic

resins with suitable combination of power and time²⁷. On the other hand, the fact that visible light cured reline resin specimens showed similar resistance with autopolymerized reline resin, and it was revealed that visible light cure resin can be an alternative reline material to autopolymerized resin. Surface preparations may influence reline bond strength of visible light cured urethane-based dimethacrylate resin. In our study, the effect of monomer wetting on the flexural strength value, although the adhesive was applied on the denture base according to the manufacturer's recommendation for the relined specimens with visible light cure resin, is statistically insignificant increase.

The bond strength between denture base and reline material is crucial factor for flexural strength of relined denture base^{19,28}. If the bond of denture base and reline material is weak, the delamination will be occurred during function^{14,29} and flexural strength of denture base will be unavoidably decreased³⁰. It may be probably explained by molecular interaction of active site between two surfaces. The low bonding ability of reline materials to denture base decrease the strength of denture and delamination occurs. Also, the weakness of the bonding causes fracture of relined denture base²⁹. The chemical similarity between the denture base and reline materials may have created a formation of an interpenetrating network and a diffuse interface. It was reported that reline resins, which have high molecular weight monomers, may not penetrate into polymer structure of denture base resin^{31,32}. Besides, Hout *et al.*¹⁴ evaluated the effect of three different self-cured hard relining materials on flexural strength of PMMA denture base material. It was stated that flexural strength of specimens relined with PMMA was significantly higher than relined with PEMA. Another explanation of decrease on flexural strength may be internal stress of denture base resin due to curing process of reline materials. Recurrent or long-term heat application could be lead to crack propagation in denture base. As a result, the strength and rigidity of realine resin may be affected negatively³¹. Similarly, in this study, the specimens which were polymerized in water bath in long-term period (MM2, MA2, ML2), showed lower flexural strength values than other polymerization techniques.

The limitation of this study was that thermal differences and loading stresses, which were exposed during clinical usage of the prosthesis, were disregarded. The specimens only were stored in water at 37°C to simulate oral conditions. Further studies are necessary to evaluate these aspects.

Conclusions

Within the limitations of this in vitro study, the following conclusions were found:

- 1- The relined specimens showed lower flexural strength, as compared to the intact specimens (control group),
- 2- Flexural strength values were different among relined denture bases,
- 3- Relining with same material and special microwave acrylic resin of denture base showed the highest flexural strength in relined denture bases,
- 4- Relining with autopolymerized acrylic resins showed the lowest flexural strength,
- 5- Relining with microwave-cured acrylic resins were as strength as the relining with the same material.

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