

Flexural Strength of Cold and Heat Cure Acrylic Resins Reinforced with Different Materials

Bijan Heidari¹, Farnaz Firouz¹, Alireza Izadi¹, Shahbaz Ahmadvand², Pegah Radan³✉

¹Assistant Professor, Department of Prosthodontic Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran

²Private Practice, Hamadan, Iran

³Postgraduate Student, Department of Prosthodontic Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran

Abstract

Objectives: Heat-polymerized acrylic resin has been the most commonly used denture base material for over 60 years. However, the mechanical strength of acrylic resin is not adequate for long-term clinical performance of dentures. Consequently, fracture is a common clinical occurrence, which often develops in the midline of the denture base. This study aimed to evaluate the efficacy of cold-cure and heat-cure acrylic resins, reinforced with glass fibers, polyethylene fibers, and metal wire for denture base repair.

Materials and Methods: Ninety specimens were prepared and allocated to nine groups. Ten specimens were considered as controls, and 80 were divided into 8 experimental groups. In the experimental groups, the specimens were sectioned into two halves from the middle, and were then divided into two main groups: one group was repaired with heat cure acrylic resin, and the other with cold cure acrylic resin. Each group was divided into 4 subgroups: unreinforced, reinforced with glass fibers, polyethylene fibers, and metal wire. All specimens were subjected to a 3-point bending test, and the flexural strength was calculated.

Results: The group repaired with heat cure acrylic resin and reinforced with glass fiber showed the highest flexural strength; however, the group repaired with cold cure acrylic resin and reinforced with polyethylene fibers had the lowest flexural strength. There was no significant difference between the groups repaired with heat cure and cold cure acrylic resins without reinforcement.

Conclusion: Repairing denture base with heat cure acrylic resin, reinforced with glass fibers increases the flexural strength of denture base.

Keywords: Strength; Denture repair; Acrylic resins; Reinforcement

Journal of Dentistry, Tehran University of Medical Sciences, Tehran, Iran (2015; Vol. 12, No. 5)

✉ Corresponding author:

P. Radan, Department of Prosthodontic Dentistry, Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran

radan.pegah@gmail.com

Received: 29 November 2014

Accepted: 20 February 2015

INTRODUCTION

Heat-polymerized acrylic resin has been the most commonly used denture base material for over 60 years. However, the mechanical strength of acrylic resin is not adequate for long-term clinical performance of dentures [1].

Therefore, fracture is a common clinical occurrence, which is often seen in the midline of denture base [2,3]. These fractures are often related to the poor fit of denture base, poorly balanced occlusion [4,5], problems in the design and manufacturing of the denture [4], low strength

of the repair material [4,5], as well as the inherent stress on the denture base, which happens over time.

In earlier studies, fracture rate was reported to be 64% [6] and 68 % [7]. These fractures may occur inside or outside the mouth due to expelling the denture from the mouth while coughing, or simply dropping it [2,5,8]. Other reasons could be excessive bite force, improper occlusal plane, high frenal attachment, lack of balanced occlusion, poor fit and poor quality of the denture base material [1]. Since fabrication of a new denture is time-consuming and costly for patients, denture repair is considered an alternative. Repaired dentures should have adequate strength, dimensional stability [4,5,8,9], and color match [4,5,8-11]; moreover, the repair should be easily and quickly performed [5,9,12], and must be affordable. Amongst various methods proposed for repairing fractured denture bases, use of auto-polymerized acrylic resins, which generally allows a simple and quick repair, is considered the most popular method. Heat-polymerized materials have been proven to have superior mechanical properties, compared to auto-polymerized materials [4,13,14]. However, laboratory packing and flasking procedures are time-consuming and are associated with the risk of denture distortion by heat [2]. Consequently, autopolymerizing resin has gained more popularity due to its easy handling, saving chairside time, and not requiring laboratory processing; moreover, the patient spends less time without denture during the repair process. In addition to the use of auto-polymerized acrylic resin, effects of reinforcement materials and surface treatment on the flexural strength of repaired dentures have been investigated in different studies [15-17].

The purpose of this study was to investigate the efficacy of two types of acrylic resins and three reinforcement materials for denture base repair.

MATERIALS AND METHODS

Materials used in this article are listed in Table 1. In the current study, we aimed to evaluate the transverse strength and modulus of elasticity of repaired acrylic denture bases using a 3-point bending test; the results were compared with those of a heat-polymerized control group. For this purpose, a stainless steel mold with internal dimensions of 10.2×70.3×3.1 mm was fabricated.

Heat cure acrylic resin (Meliodent, Heraeus Kulzer, Germany) was mixed in accordance with the manufacturer's instructions, and placed in the prepared mold and packed in the flask. The flask was transferred to a spring clamp. Acrylic resin specimens were processed for 9 hours in water bath, and kept at a constant temperature of 165°F (73.5°C). Afterwards, 90 acrylic samples were fabricated and the superior surfaces of acrylic samples were polished. All samples were stored in distilled water at 37°C for 48 hours before the test, and the prepared samples were randomly distributed into 9 groups (C, HN, HG, HM, HP, CN, CG, CM, and CP).

The prepared intact specimens were cut vertically in half along their long axis (except for 10 specimens, which were allocated to the control group, that is group HG) by a high-speed diamond disk cutter under copious irrigation, until 3mm space was created between the two pieces. After the treatment of fractured surfaces, the heat-polymerized strip haves were fixed to a metal mold to provide space for placing the repairing resin.

Table 1. The materials used in this study

Material	Product Name	Manufacturer
Heat-polymerizing acrylic resin	Meliodent	Heraeus Kulzer, Hanau, Germany
Autopolymerizing acrylic resin	Meliodent	Heraeus Kulzer, Hanau, Germany
Woven glass fibers	Ribbon	Angelus, Brazil
Woven metal wire	S.S metal wire	Dentaurum, Germany
Woven polyethylene fibers	Ribbon	Angelus, Brazil

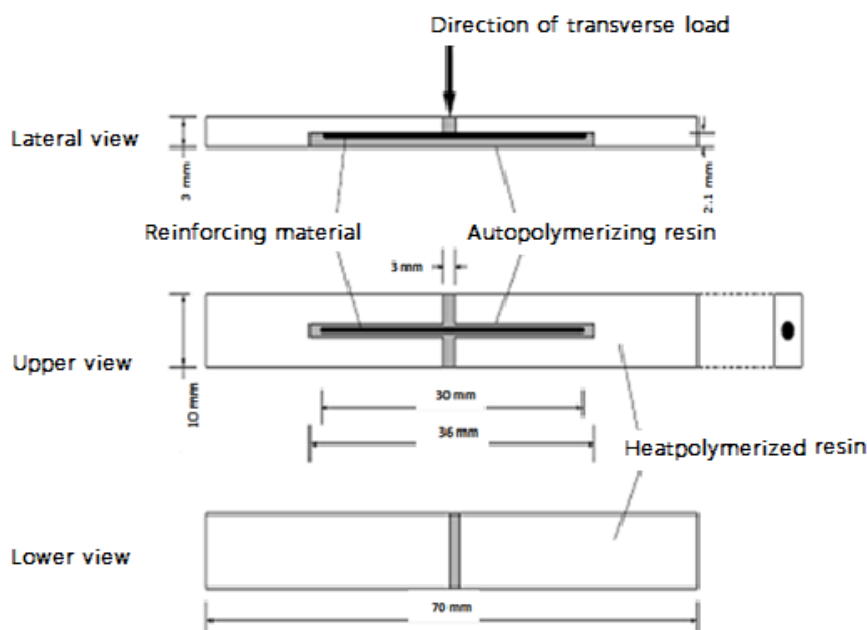


Fig. 1. The schematic view of 3-point bending test

A groove with 36 mm length, 3 mm width, and 2.1 mm depth was prepared on all samples for placing the reinforcing materials. After placing the reinforcing materials, samples were repaired with cold/heat cure resins and prepared for 3-point bending test.

The specimens were repaired as follows:

Group C: control group with no fracture,

Group HN: repaired with heat cure acrylic resin with no reinforcement,

Group HG: repaired with heat cure acrylic resin, and reinforced with glass fiber,

Group HM: repaired with heat cure acrylic resin, and reinforced with metal wire (1 mm in diameter),

Group HP: repaired with heat cure acrylic resin, and reinforced with polyethylene,

Group CN: repaired with cold cure acrylic resin with no reinforcement,

Group CG: repaired with cold cure acrylic resin, and reinforced with glass fiber,

Group CM: repaired with cold cure acrylic resin and reinforced with metal wire (1 mm in diameter), and

Group CP: repaired with cold cure acrylic resin and reinforced with polyethylene.

Fibers in group HG and CG were placed vertically along the groove alignment. The repaired specimens were prepared and subjected to thermal cycling in water baths between 5°C and 55°C with a 30-second dwell time for 500 cycles. Each specimen was subjected to 3-point bending test, using the universal testing machine (Zwick Roell, Germany) at a crosshead speed of 8 mm/min at 50mm distance (Fig. 1). In the experimental groups, the load was applied to the center of 2mm repaired area, and to the center in the control group.

The materials used in this study included a heat-polymerized acrylic resin (Meliodent Heat Cure, Heraeus Kulzer, Germany) used as the base, an auto-polymerized acrylic resin (Meliodent, Heraeus Kulzer, Germany) used as the repair material, and three reinforcement materials including woven stainless steel wire (1 mm in diameter), glass fibers (Ribbon, Angelus, Brazil) and woven polyethylene ribbon fibers (Ribbon, Angelus, Brazil).

Statistical Analysis

The measured variables were coded and entered into SPSS version 16.

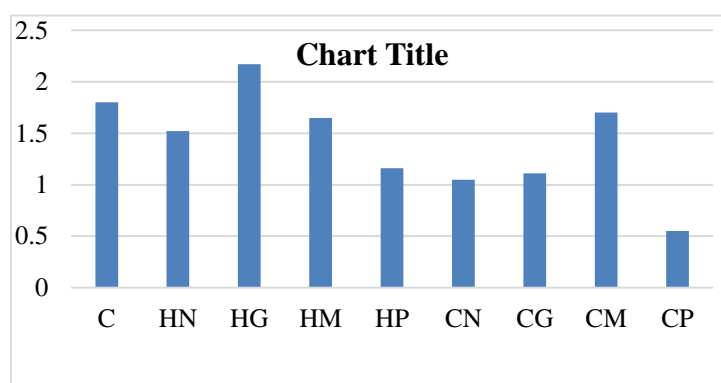


Fig. 2. The mean value of flexural strength in different groups

All data were statistically analyzed with one-way and two-way ANOVA, and the differences among the groups were assessed using the Tukey's test and Dunnett's post-hoc test. P-values less than 0.05 were considered statistically significant.

RESULTS

The mean value of the flexural strength in the control group (no fracture) was 1.8 ± 0.202 MPa. Group HG (repaired with heat-cured acrylic resin reinforced with glass fiber) and group CP (repaired with cold-cured acrylic resin reinforced with polyethylene) showed maximum (2.17 ± 0.32 MPa) and minimum (0.55 ± 0.15 MPa) flexural strength values, respectively. The mean flexural strength and standard deviation values were 1.7 ± 0.474 MPa for group CM, 1.51 ± 0.303 MPa for group HN, 1.16 ± 0.383

MPa for group HP, 1.11 ± 0.244 MPa for group CG and 1.05 ± 0.331 MPa for group CN. Table 2 shows the comparison of flexural strength of different groups based on the reinforcing materials used in each group.

Fig. 2 shows the flexural strength in different groups. Analysis of one-way ANOVA followed by Dunnett's test showed a statistically significant difference between the control group and all the experimental groups except for the control group and group HN.

Two-way ANOVA followed by Tukey's test revealed significant differences between groups reinforced with different materials except between the polyethylene and metal wire groups.

The effect of reinforcement with various materials on the flexural strength is shown in Table 3.

Table 2. The mean and standard deviation of the flexural strength of the groups

Study groups	Mean \pm SD (MPa)
Group CM	1.7 ± 0.474
Group HN	1.51 ± 0.303
Group HP	1.16 ± 0.383
Group CG	1.11 ± 0.244
Group CN	1.05 ± 0.331

DISCUSSION

In this study, the values of flexural strength of cold cure acrylic resin with no reinforcement (group CN) and cold cure acrylic resin with glass fiber reinforcement (group CG) were lower than that of the control group (with no fracture). Polyzois et al reported higher fracture strength in specimens repaired with cold cure acrylic resin without reinforcement and those reinforced with glass fiber (in comparison with the control group with no fracture) [12]. In our study, there was a difference between the control group and the group repaired with cold cure acrylic resin, reinforced with metal wire; however, according to Polyzois's study, the strength of the specimens repaired with cold cure acrylic resin reinforced with metal wire was more than that of the control group with no fracture [12]. Results of their study were in contrast to ours. In the current study, the flexural strength of the control group was greater than that of the groups repaired with cold cure acrylic resin, cold cure acrylic resin reinforced with fiber glass, and cold cure acrylic resin reinforced with metal wires, which is similar to the findings of Nagai's study [19].

In their study, glass fibers showed greater strength in comparison with metal fibers, although both were stronger than the specimens repaired with cold cure acrylic resin only. However, in contrast to the mentioned study, in the current study, the strength created with glass fibers was greater than that of metal wires.

In both studies, the strength of repaired specimens with glass fibers and metal wire was greater than that of cold cure acrylic resin without reinforcement; however, Nagai also showed the greater strength of intact denture in comparison with the repaired denture [19]. In another study, Keyf et al revealed that the strength of repaired specimens was lower than that of the intact specimens [20].

In the current study, lower strength was recorded for cold cure acrylic resin in comparison with heat cure acrylic resin. Studies by Leong and Grant, Berge, and Rached et al showed that dentures repaired with cold cure acrylic resin broke at the repaired site, which may be due to the lower strength of cold cure acrylic resin; these results confirm our findings [21-23].

Lower strength of cold cure acrylic resin seems to be due to the insufficient polymerization process [24].

In the current study, the mean value of the flexural strength of group HP was 56.8% of that of control specimens; this is generally lower than the results of previous studies, which used cold cure acrylic resin for repair of specimens with heat-polymerized resin. On the other hand, the reported values in similar studies were 60% to 65%. For instance, in Berge's study [22], the reduction of the strength of dentures repaired with cold cure acrylic resin compared to the controlled prototypes was reported to be 60%. Similarly, this value in a study conducted by Leong and Grant was reported to be 65%.

Table 3. The effect of reinforcement with various materials based on the flexural strength of the samples in comparison with the control group

Comparison group	Evaluation	Type of reinforcing	Effect based on flexural strength
Heat-cure acrylic resin		Glass fibers *	increase
		Metal wire	increase
		Polyethylene	decrease
Cold-cure acrylic resin		Glass fibers	increase
		Metal wire	increase
		Polyethylene**	decrease

*: P=0.001

** : P=0.022

In the current study, the flexural strength of group HN was 84% of the control group and 75% of the value reported by Leong and Grant; in Stipho's study, the recorded value was 80% [23,25].

As previously mentioned, there are other studies investigating the effect of surface treatment on flexural strength. For instance, Pereira et al [16] evaluated the effect of abrasion of fracture surfaces with silicon carbide abrasive papers and/or wetting them with methyl methacrylate. According to their study, the flexural strength of samples wetted with methyl methacrylate was greater than other groups, except for the control group. In another study, Thunyakitpisal et al [15] evaluated the effect of methyl methacrylate, methyl formate, methyl acetate, a mixture of methyl formate-methyl acetate and Re-base II adhesive on repaired specimens. They concluded that treating surfaces with methyl formate, methyl acetate, and a mixture of methyl formate-methyl acetate solutions significantly enhanced the flexural strength of heat-polymerized acrylic denture base resin repaired with auto-polymerized acrylic resin.

Although several studies including the present one have reported higher strength of denture base repaired with heat-polymerized acrylic resin, use of heat cure acrylic resin is less common due to different factors such as the necessity to use a mold (custom split cast gypsum mold), longer polymerization time, higher laboratory costs and patients requiring dentures at a sooner time.

On the other hand, repairing denture base with cold cure acrylic resin is faster, easier and more practical [18].

In order to enhance the mechanical properties and flexibility of denture base, metal wires and various fibers such as glass fibers can be used. It has been indicated that glass fibers significantly increase the strength of dentures. In this study, glass fibers, metal wires and polyethylene fibers were used to strengthen the repaired dentures [25].

Compared with the control group, the highest flexural strength was observed in the group repaired with heat cure acrylic resin, reinforced with glass fibers; the difference was statistically significant. Stipho and Talic also showed that incorporation of glass fibers into polymethyl methacrylate increased the strength of acrylic resin [25].

Polyzois et al showed that incorporation of metal wire into acrylic resin increased the fracture and flexural strengths. He reported that metal wire incorporation plays an important role in improving the mechanical properties of acrylic resin [5]. In a different study, Polyzois et al suggested the use of metal wire to strengthen the repaired bases [12]; while an investigation by Minami et al showed increased strength of denture base with the use of metal wires (stainless steel or Co-Cr-Ni wire) [26].

The strength of restorative materials for repairing denture base can be measured using transverse, shear and twisting strength tests. Today, transverse strength test is more common, and can be performed with 3- or 4-point loading.

The difference between these two types is in their maximum flex point. Four-point loading technique is more favorable due to its better quality control and correspondence with standards; however, its validity for repaired denture base is doubtful, since the stress distribution pattern at the interface of base and repairing material is not known [18,27].

CONCLUSION

The present study showed that there was no significant difference between the groups repaired with heat cure and cold cure acrylic resins without reinforcement. Moreover, our findings revealed that repairing denture base with heat cure acrylic resin, reinforced with glass fibers increased the flexural strength of denture base. Finally, among materials used in this study, repairing the denture base with heat cure acrylic resin reinforced with glass fibers showed the greatest flexural strength.

REFERENCES

- 1- Beyli MS, von Fraunhofer JA. An analysis of causes of fracture of acrylic resin denture. *J Prosthet Dent.* 1981 Sep;46(3):238-41.
- 2- Beyli MS, von Fraunhofer JA. An analysis of causes of fracture of acrylic resin dentures. *J Prosthet Dent.* 1981 Sep;46(3):238-41.
- 3- Darbar UR, Huggett R, Harrison A. Denture fracture - a survey. *Br Dent J.* 1994 May 7;176(9):342-5.
- 4- Beyli MS, von Fraunhofer JA. Repair of fractured acrylic resin. *J Prosthet Dent.* 1980 Nov;44(5):497-503.
- 5- Polyzois GL, Andreopoulos AG, Lagouvardos PE. Acrylic resin denture repair with adhesive resin and metal wires: effects on strength parameters. *J Prosthet Dent.* 1996 Apr;75(4):381-7.
- 6- Vallittu PK, Lassila VP, Lappalainen R. Evaluation of damage to removable dentures in two cities in Finland. *Acta Odontol Scand.* 1993 Dec;51(6):363-9.
- 7- Hargreaves AS. The prevalence of fracture in dentures. *Br Dent J.* 1969 May 20;126(10):451-5.
- 8- Stipho HD, Stipho AS. Effectiveness and durability of repaired acrylic resin joints. *J Prosthet Dent.* 1987 Aug;58(2):249-53.
- 9- Ward JE, Moon PC, Levine RA, Behrendt CL. Effect of repair surface design, repair material, and processing method on the transverse strength of repaired acrylic denture resin. *J Prosthet Dent.* 1992 Jun;67(6):815-20.
- 10- John J, Gangadhar SA, Shah I. Flexural strength of heat polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers. *J Prosthet Dent.* 2001 Oct;86(4):424-7.
- 11- Ng ET, Tan LH, Chew BS, Thean HP. Shear bond strength of microwaveable acrylic resin for denture repair. *J Oral Rehabil.* 2004 Aug;31(8):798-802.
- 12- Polyzois GL, Tarantili PA, Frangou MJ, Andreopoulos AG. Fracture force, deflection at fracture, and toughness of repaired denture resin subjected to microwave polymerization or reinforced with wire or glass fiber. *J Prosthet Dent.* 2001; 86:613-9.
- 13- Dar-Odeh NS, Harrison A, Abu-Hammad O. An evaluation of self cured and visible light-cured denture base materials when used as a denture base repair material. *J Oral Rehabil.* 1997 Oct;24(10):755-60.
- 14- Polyzois GL, Handley RW, Stafford GD. Repair strength of denture base resins using various methods. *Eur J Prosthodont Restor Dent.* 1995 Jun;3(4):183-6.
- 15- Thunyakitpaisal N, Thunyakitpaisal P, Wiwatwarapan C. The effect of chemical surface treatments on the flexural strength of repaired acrylic denture base resin. *J Prosthodont.* 2011 Apr;20(3):195-9.
- 16- Pereira Rde P, Delfino CS, Butignion LE, Vaz MA, Arioli-Filho JN. Influence of surface treatments on the flexural strength of denture base repair. *Gerodontology.* 2012 Jun;29(2):e234-8.
- 17- Arioli-Filho JN, Butignion LE, Pereira Rde P, Lucas MG, Mollo-Fde A Jr. Flexural strength of acrylic resin repairs processed by different methods: water bath, microwave energy and chemical polymerization. *J Appl Oral Sci.* 2011 May-Jun;19(3):249-53.
- 18- Seó RS, Neppelenbroek KH, Filho JN. Factors affecting the strength of denture repairs. *J Prosthodont.* 2007 Jul-Aug;16(4):302-10.
- 19- Nagai E, Otani K, Satoh Y, Suzuki S. Repair of denture base resin using woven metal and glass fiber: effect of methylene chloride pretreatment. *J Prosthet Dent.* 2001 May;85(5):496-500.
- 20- Keyf F, Uzun G. The effect of glass fiber-reinforcement on the transverse strength, deflection and modulus of elasticity of repaired acrylic resins. *Int Dent J* 2000 Apr; 50:93-7.
- 21- Rached RN, Powers JM, Del Bel Cury AA. Repair strength of auto polymerizing, microwave, and conventional heat-polymerized acrylic resins. *J Prosthet Dent* 2004 Jul; 92:79-82.
- 22- Berge M. Bending strength of intact and repaired denture base resins. *Acta Odontol Scand.*

- 1983 Jun;41(3):187-91.
- 23- Leong A, Grant AA. The transverse strength of repairs in polymethyl methacrylate. *Aust Dent J.* 1971 Aug;16(4):232-4.
- 24- Vallittu PK. The effect of surface treatment of denture acrylic resin on the residual monomer content and its release into water. *Acta Odontol Scand.* 1996 Jun;54(3):188-92.
- 25- Stipho HD, Talic YF. Repair of denture base resins with visible light-polymerized reline material: Effect on tensile and shear bond strengths. *J Prosthet Dent.* 2001 Aug;86(2):143-8.
- 26- Minami H, Suzuki S, Kurashige H, Minesaki Y, Tanaka T. Flexural strengths of dental base resin repaired with auto polymerizing resin and reinforcements after thermo cycle stressing. *J Prosthodont.* 2005 Mar;14(1):12-8.
- 27- Chitchumnong P, Brooks SC, Stafford GD. Comparison of three- and four-point flexural strength testing of denture base polymers. *Dent Mater.* 1989 Jan;5(1):2-5.