

Flexural strength of acrylic resin repairs processed by different methods: water bath, microwave energy and chemical polymerization

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ABSTRACT

Denture fractures are common in daily practice, causing inconvenience to the patient and to the dentists. Denture repairs should have adequate strength, dimensional stability and color match, and should be easily and quickly performed as well as relatively inexpensive. Objective: The aim of this study was to evaluate the flexural strength of acrylic resin repairs processed by different methods: warm water-bath, microwave energy, and chemical polymerization. Material and methods: Sixty rectangular specimens (31x10x2.5 mm) were made with warm water-bath acrylic resin (Lucitone 550) and grouped (15 specimens per group) according to the resin type used to make repair procedure: 1) specimens of warm water-bath resin (Lucitone 550) without repair (control group); 2) specimens of warm water-bath resin repaired with warm water-bath; 3) specimens of warm water-bath resin repaired with microwave resin (Acron MC); 4) specimens of warm water-bath resin repaired with autopolymerized acrylic resin (Simplex). Flexural strength was measured with the three-point bending in a universal testing machine (MTS 810 Material Test System) with load cell of 100 kgf under constant speed of 5 mm/min. Data were analyzed statistically by Kruskal-Wallis test ($p < 0.05$). Results: The control group showed the best result (156.04 ± 1.82 MPa). Significant differences were found among repaired specimens and the results were decreasing as follows: group 3 (43.02 ± 2.25 MPa), group 2 (36.21 ± 1.20 MPa) and group 4 (6.74 ± 0.85 MPa). Conclusion: All repaired specimens demonstrated lower flexural strength than the control group. Repairs with autopolymerized acrylic resin showed the lowest flexural strength.

Key-words: Flexural strength. Denture fracture. Denture repair.

INTRODUCTION

Fractures of the base of poly (methyl)-methacrylate dentures are common in clinical practice, happening more frequently in the midline of maxillary complete dentures^{3,5}. These fractures are often related to poor fit of the denture base^{4,16}, poorly balanced occlusion^{4,16}, problems in design and manufacturing of the denture⁴, poor strength of the repair material^{4,16}, as well as inherent stress on the denture base that happens over time^{16,29}.

Denture fractures occur outside and inside the mouth. Outside the mouth, they often occur as a consequence of impact (accidents), as a result of expelling the denture from the mouth while coughing, or simply of dropping the denture^{3,16,22}. Inside, the causes of denture fracture can be excessive bite force, improper occlusal plane, high frenal attachment, lack of balanced occlusion, poor fit or limitations in denture base material¹. When in function, midline fracture is the result of flexural fatigue failure caused by cyclic deformation of the base, and is more likely to occur because flexure of

the denture base occurs along the midline²¹.

Denture repairs should have adequate strength, dimensional stability^{4,16,22,27}, good color match^{4,10,15,16,22,27}, are easily and quickly performed^{16,18,27}, are relatively inexpensive^{10,15,27}. Factors affecting adhesion and the mechanical properties of the repair material can influence the strength of the repaired denture. Attempts to improve the bond strength between the denture base resin and the repair material, through mechanical or chemical surface modification^{9,14,21,25,27}, as well as the transverse strength, by metal wiring or fiber reinforcements^{10,11,14,18,25}, have been described. The choice of denture base resin, as well as of the repair material may also influence the strength of the repaired denture^{5,6,15,19,23,24}.

Heat-polymerized materials have been proven to have higher mechanical properties when compared with auto-polymerized materials^{4,6,17}. However, laboratory packing and flasking procedures are time consuming and present risk of denture distortion by heat⁸.

Comparing the different repair techniques, was described that acrylic resins, when polymerized under pressure and then stored in water, were more resistant than those polymerized by trade polymerization method¹³. Accordingly, considering the variability of the repair materials and the different repairing techniques, herein we aimed at assessing the flexural strength of acrylic resin repairs using different processing techniques. It is expected that the different methods of polymerization of acrylic resins used to repair specimens allow flexural strength values similar to those of the non-repaired specimens.

MATERIAL AND METHODS

One control and three experimental groups (n=15) were formed according to the type of resin used for repairing specimens made of Lucitone 550 thermoactivated acrylic resin (Dentsply Trubite, York, PA, USA): 1) Control - no repair; 2) repair with Lucitone 550; 3) repair with Acron MC thermoactivated acrylic resin (GC Dental Ind. Corporation, Alsip, IL, USA); 4) repair with Simplex chemically activated acrylic resin (Artigos Odontológicos Clássicos, São Paulo, SP, Brazil).

Metal master pattern with rectangular cavities associated to a metal spacer bar with 3.0x10.0x2.5 mm³ placed in the center of this pattern were used to make repaired specimens measuring 65.0x10.0x2.5 mm³, according to the Specification No.12 of the American Dental Association (Figure 1).

Pattern was initially isolated with a thin layer of acrylic separating film (Cel-Lac, S.S. White, Rio de Janeiro, RJ, Brazil) and included in special flasks (Provecto Analítica, Jundiaí, SP, Brazil) that can be

used in the microwave oven reinforced with stone plaster type III Herodent (Cremer, São Paulo, SP, Brazil). With the plaster still fluid, one matrix was placed on each flask, maintaining its superior face exposed. After 60 min, each matrix compartment was filled with liquid wax (Kota Imports, São Paulo, SP, Brazil), and the counter flask was again filled with a new portion of stone plaster type III. The specimens of control group were made without use of the metal spacer bar.

After setting of the stone, the flask was opened and the wax was removed with hot water. The inner surface of the metal pattern was coated with acrylic separating film and the cavities were filled with acrylic resin (Lucitone 550), mixed according to the manufacturer's instructions, keeping the metal spacer bar placed only to groups 2, 3 and 4. The flask was closed to be pressed in a hydraulic press (Delta, Delta Máquinas Especiais, Vinhedo, SP, Brazil). A cellophane sheet was placed over acrylic resin before the flask was closed. The initial pressing was carried out with 800 kg to eliminate excess resin. Then, the flask was opened, the cellophane sheet was removed and a second pressing was carried out with 1,250 kg for 30 min. After this

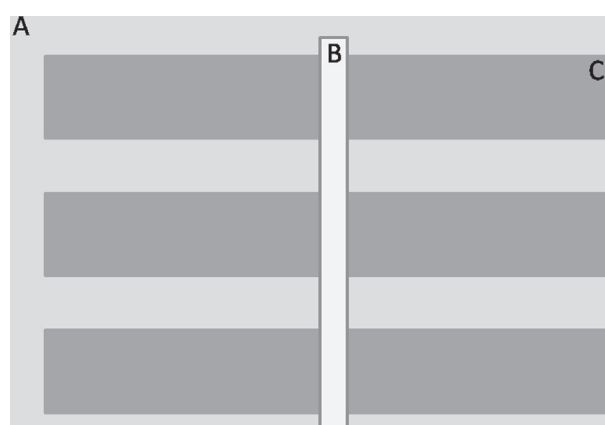


Figure 1- A) Metal master pattern; B) Spacer Bar, and C) Rectangular cavities

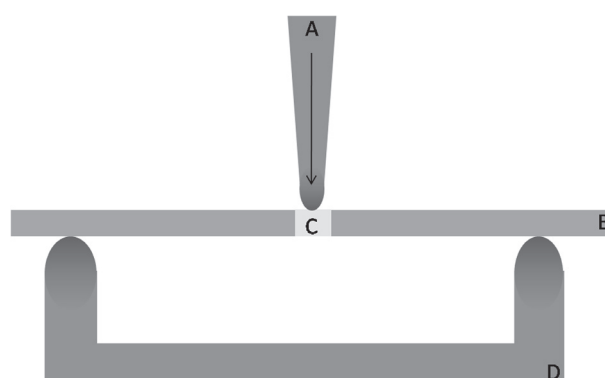


Figure 2- Scheme of test in MTS 810: A) round-end point, B) resin specimen, C) resin repair, and D) support for specimen

procedure, the flask was immersed in water at 74°C for 9 h in a polymerization unit (Termotron P-100, Termotron do Brasil Ltda, São Paulo, SP, Brazil). After being left at room temperature (26°C), the flasks were carefully opened and the metal spacer bar was removed. The acrylic specimens were also removed and abraded with 200-, 400-, 600-, 1000-, 1500-grit silicon carbide paper (Norton, Comercial e Técnica de Abrasivos Ltda., Campinas, SP, Brazil) in a decreasing sequence of abrasiveness, followed by final polishing with 1 µm diamond paste. All specimens were stored in distilled water at 37°C for 1 week before repair.

Each specimen was then replaced on the flasks in order to maintain a uniform space for the repair material and to determine the alignment of the specimens. For all groups butt joint surfaces without treatment was produced.

Upon removal of the space bar, the 2 sections of the specimens were repaired using the 3 different acrylic resins. In group 2, repairs were done with acrylic resin Lucitone 550, prepared according to the manufacturer's recommendations. Lucitone 550 resin was placed under compression (1250 kg) for 30 min at room temperature, and polymerized in short-cycle water bath (60 min under 100°C degrees)²⁶. Specimens of group 3 were repaired using acrylic resin Acron Mc, also under same compression for 30 min, at room temperature (23°C) and polymerized in a domestic microwave

(Sensor Crisp 38, Brastemp, Manaus, AM, Brazil) for 3 min at 500 W¹⁷. Finally, in group 4, repair materials were chemically polymerized and placed in the flask, under same compression, in water bath (55°C for 15 min)²⁶. This method was conducted in order to improve their physical properties²⁵ and standardize the amount of material to be used in the repair. Prior to the flexural strength tests, all specimens were stored again in distilled water at 37°C for 1 week.

The three-point bending flexural strength test was conducted in a computerized device for mechanical assays (MTS-810 - MTS Systems Corporation, Eden Prairie, MN-USA) with load cell of 100 kgf under constant speed of 5 mm/min⁶. Force was applied in the center of the specimens (repair area)^{4,25}, in opposition to the supports, with a round-end point. Force was uniformly increased until fracture of the specimens (Figure 2). The maximum load applied was registered and calculated in N.

The maximum load applied was used to calculate the flexural strength by means of the specimens' cross sectional area, according the following equation:

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

Where: S = transverse strength; W = load at fracture, L = distance between supporting wedges (50 mm); b = width of the specimen (10 mm); d = thickness of the specimen (2.5 mm).

Table 1- Measurements of rupture tension in the MPa, standard deviation (SD), mean and median

Specimens	Resins			
	Control	Lucitone 550	Acron MC	Simplex
1	158.008	37.536	41.822	7.215
2	153.408	35.285	46.700	7.543
3	153.510	38.629	44.772	6.845
4	157.037	34.171	44.747	8.694
5	157.328	36.416	42.266	6.014
6	158.937	35.648	45.746	7.598
7	155.552	36.149	42.716	5.780
8	154.768	34.422	40.839	6.903
9	156.347	35.645	39.896	5.841
10	154.301	36.470	41.956	5.527
11	154.647	37.457	45.532	6.478
12	155.496	35.698	40.562	7.210
13	157.903	36.531	39.587	5.987
14	154.838	37.469	44.329	6.432
15	158.607	35.699	43.872	7.025
SD	1.832	1.205	2.257	0.856
Mean	156.046	36.215	43.023	6.742
Median	155.552	36.149	42.716	6.845

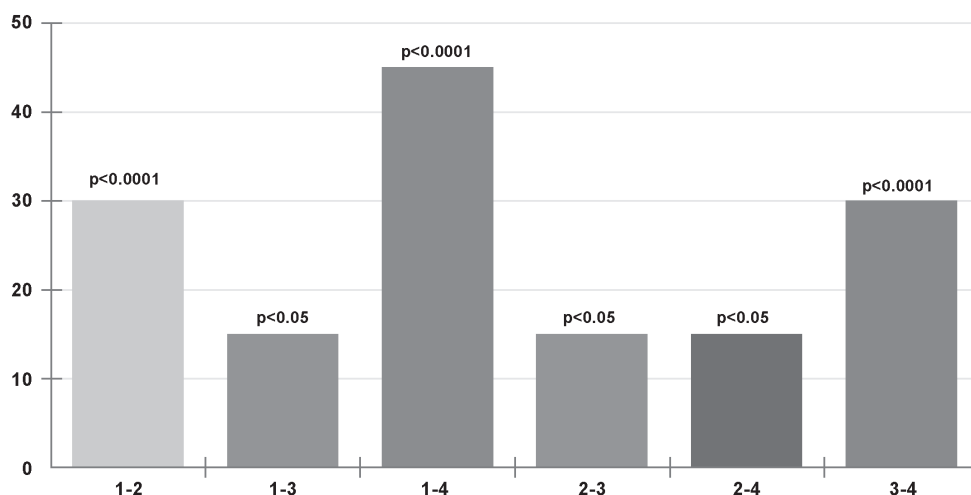


Figure 3- Intergroup comparisons (Kruskal-Wallis; $p < 0.05$)

Preliminary analysis of data showed a non-normal distribution. Thus, the Kruskal-Wallis non-parametric test was adopted to analyze the results ($p < 0.05$) followed by Student-Newman-Keuls test for multiple comparisons. Statistical analysis was done using BioStat 5.0 software (AnalystSoft, Vancouver, BC, Canada).

RESULTS

Table 1 presents flexural strength values of each group, standard deviation (SD), mean and median for the all groups. There was significant difference among groups ($p < 0.05$), as demonstrated by Kruskal Wallis statistical test and Student-Newman-Keuls for statistical comparison Figure 3.

The best result was demonstrated by group 1 (control) followed by group 3 (microwave), 2 (warm water-bath) and 4 (chemical polymerization), in a decreasing order of strength. The flexural strength of group 3 was up to 27% of the intact specimens' strength. The types of failures of the specimens were not observed in this study.

DISCUSSION

This study assessed the flexural strength of 3 different types of acrylic resins, used in the repair of rectangular specimens produced with acrylic resins by different methods of polymerization. The repair material of choice depends on the following factors: length of time required for making the repair, transverse strength obtained with the repair material, and degree to which dimensional accuracy is maintained during the repair. Other important factor is that the increase in the temperature of polymerization improves mechanical and chemical properties of acrylic resins⁷.

All repaired groups demonstrated flexural

values lower than that of the intact specimens in this study. The hypothesis tested in this study was thus rejected. It was found in test group that microwave-cured resin had the highest intact transverse strength with a mean value of 43.023 MPa, followed by warm water-bath-cured resin, with a mean value of 36.215 MPa and chemically polymerized resin with a mean value 6.742 MPa.

The increased transverse strength of microwave-cured resin (Acron MC) was probably due to the presence of less rubber in its composition as compared to conventional warm water-bath-cured resin (Lucitone 550), which makes the last one behave more elastically, demonstrating low final strength values²⁰. Moreover, some studies have shown that microwave-cured resins have decreased porosity because the heat necessary to break the benzoyl peroxide molecule into free radicals is created inside the resin once microwave radiations have greater penetrating capability^{15,20}. This way, the heat is dispersed more efficiently and polymerization is rapid and decreases residual monomer content as compared to warm water-bath-cured resin.

On the other hand, in this study, chemical polymerizing showed the worst flexural strength values mean, when compared to the others groups, in agreement with other study²⁵. This method is the most commonly used for denture repairs in daily practical. However, it has been shown that, not all the monomer is converted to polymer in denture repair, and the level of residual monomer has been demonstrated to affect other properties. It is possible that the repair strength could be improved by effecting further polymerization like microwave energy or warm water-bath²⁸. A way to improve the performance of this type of polymerization is that dentures repaired with auto-polymerized acrylic resin should be stored in water for a time between

24 h and 1 week before being installed, allowing to the complete polymerization of the material⁹. However, it is important to consider that in clinical practice there is often urgency in repairing dentures, which make the time recommended by the authors unfeasible, in order to avoid embarrassing situations for the patients.

As all *in vitro* studies, the present research has limitations. Although this work compared different methods of polymerization, one of the limitations of this study is the use of resins of different commercial brands and compositions. However, the methods can be used safely for comparisons, once it agrees with the studies cited previously^{20,25,28}. Further research is needed to evaluate these results under conditions that simulate a clinical situation like thermal cycling and/or cyclic loading.

CONCLUSIONS

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

- 1- The repaired specimens showed lower flexural strength, as compared to the intact specimens (control group);
- 2- Repairs with autopolymerized acrylic resins showed the lowest flexural strength;
- 3- Final results are influenced by the repair material.

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