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| ORIGINAL

Effect of different materials for temporary removable partial denture: an in vitro study on surface roughness and fracture resistance

Efeito de diferentes materiais para confecção de prótese parcial removível provisória: um estudo in vitro sobre rugosidade superficial e resistência à fratura

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ABSTRACT

The use of removable partial dentures is considered a common and inexpensive treatment option to rehabilitate edentulous areas. The aim of this study was to evaluate the effect of different materials for provisional removable partial dentures, an in vitro study on surface roughness and fracture resistance. Thermopolymerizable acrylic resin and thermoplastic resin specimens with dimensions of 10 x 10 x 2 mm (blocks) (n=10) and with dimensions of 65 x 20 x 3 mm (bars) (n=10 were analyzed for their surface roughness (Ra) and three-point flexural strength test. All specimens were subjected to oven aging for 60 days at 37°C±0.5°C in distilled water. The statistical analysis was performed with a significance level of 5%, and the surface roughness data were submitted to the Two-way Anova statistical test ($P < 0.05$) and the mechanical strength data were subjected to One-way Anova statistical test ($P < 0.05$). For roughness, the factor resin type ($P = 0.000$) and the factor aging ($P = 0.000$) were statically significant, as well as showing interaction ($P = 0.228$). The Thermopolymerizable acrylic resin had the lowest mean roughness values compared to the thermoplastic resin and showed no statistical difference after aging. The same scenario was repeated for flexural strength values; Thermopolymerizable acrylic resin was statistically superior to thermoplastic resin ($P = 0.000$). Thermopolymerized acrylic resin showed lower surface roughness values and higher flexural strength values compared to thermoplastic resin.

Indexing terms: Dental prosthesis. Flexural strength. Polymers.

RESUMO

O uso de próteses parciais removíveis é considerado uma opção de tratamento comum e de baixo custo para reabilitar áreas edêntulas. O objetivo deste estudo foi avaliar o efeito de diferentes materiais para próteses parciais removíveis provisórias, um estudo in vitro sobre rugosidade superficial e resistência à fratura. Espécimes de resina acrílica termopolimerizável e de resina termoplástica com

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dimensões de 10 x 10 x 2 mm (blocos) (n = 10) e de 65 x 20 x 3 mm (barras) (n = 10) foram analisados em rugosidade superficial média (Ra) e teste de resistência à flexão de três pontos. Todos os espécimes foram submetidos ao envelhecimento em estufa por 60 dias a 37 ° C ± 0,5 ° C em água destilada. A análise estatística se deu com nível de significância de 5%, e os dados de rugosidade superficial foram submetidos ao teste estatístico Anova dois fatores (P <0,05) e os dados de resistência mecânica foram submetidos ao teste estatístico Anova um fator (P <0,05). Para rugosidade, o fator tipo resina (P = 0,000) e o fator envelhecimento (P = 0,000) foram estatisticamente significantes, além de apresentar interação (P = 0,228). A resina acrílica termopolimerizável apresentou menores valores médios de rugosidade em relação à resina termoplástica e não apresentou diferença estatística após envelhecimento. O mesmo cenário foi repetido para valores de resistência à flexão; a resina acrílica termopolimerizável foi estatisticamente superior à resina termoplástica (P = 0,000). A resina acrílica termopolimerizada apresentou menores valores de rugosidade superficial e maiores valores de resistência à flexão em relação à resina termoplástica.

Termos de indexação: *Prótese dentária. Resistência à flexão. Polímeros.*

INTRODUCTION

The use of removable partial dentures (RPDs) is considered a common and inexpensive treatment option to rehabilitate edentulous areas [1]. Temporary RPDs are a transitional therapy for patients who have suffered the immediate loss of dental elements, as in cases where final metal-framed RPPs cannot be made. Thermally cured polymethyl methacrylate resin (PMMA), called Thermopolymerizable resin, has been used for many years to make the denture base of a final and a temporary RPD [2]. This material is rigid, easy to be relined, repaired, adjusted and polished, but its disadvantages are its toxicity, which is harmful to patients with allergic reactions to the monomer, and its high porosity, which may cause changes in the patient's mucosa due to accumulation of debris [3].

In an attempt to solve the disadvantages presented by thermopolymerizable acrylic resin, to promote greater comfort for the patient and esthetics, thermoplastic resins have emerged for the construction of flexible temporary prostheses [3,4]. Flexible prostheses have been widely used in some countries and due to the growing popularity in the media; the thermoplastic (flexible) resin presents impact strength values similar to those of conventional resins (PMMA), thus showing that this material can be adopted in the long term [5]. Besides the promising results regarding mechanical strength [2], microhardness, solubility and sorption [6]. There are no clinical researches or studies on the long-term effects of flexible resins [3]. The literature is scarce regarding researches on the use of thermoplastic resins, there are many publications of clinical cases and literature reviews. Therefore, scientific evidence is required for the safe indication of this material by the dentist for the fabrication of temporary RPDs.

Based on the above, this study aimed to evaluate the effect of different materials for fabrication of provisional partial dentures, an in vitro study on surface roughness and fracture resistance. The expected results for this research are: Null Hypothesis (H0): There will be no statistically significant differences between different materials for making provisional removable partial dentures, regarding the values of surface roughness and mechanical strength; Alternative Hypothesis 1 (H1): There will be statistically significant differences between different materials for making provisional removable partial dentures, regarding the values of surface roughness and mechanical strength.

METHODS

Specimen preparation

Specimens were made using thermopolymerizable acrylic resin (Conventional) (VIPI Produtos Odontológicos, Pirassununga, São Paulo, Brazil) and thermoplastic resin (Flexible, polypropylene) (Odontoflex, Osasco, São Paulo, Brazil) with the aid of addition reaction silicone molds (3M ESPE, Bayern, Germany), with dimensions of 10 x 10 x 2 mm (blocks) and dimensions of 65 x 20 x 3 mm (bars). The blocks were used for surface analysis and the bars according to ADA specification 12.2 for mechanical testing. Wax patterns 7 were made in the silicone matrices, so that it was possible to produce the specimens, according to the polymerization recommendations of the manufacturers; for acrylic resin it was the conventional polymerization and for flexible resin it was the injection polymerization.

After finishing the polymerization process, the lateral excesses were removed with a handpiece bur, and the dimensions of the specimens were checked with the aid of a digital pachymeter. Polishing was performed on only one face of the specimens, with siliconized rubbers (Acrylic Polisher Exa-Technique PM; Edenta - Labordental, São Paulo-SP), in the green, black and yellow sequence, each one acting on the surface for 1 min; followed by a brush for scratch removal (Brithe Red Coarse Scotch Brush PM, American Burrs, Palhoça -SC); brush for polishing (Suede brush, Derfla - Labordental, São Paulo-SP, Brazil) and brush for polishing and final brightness (Felt Brush for Polishing PM, American Burrs, Palhoça -SC), each brush acting on the material for 1 min. The other side remained unpolished, because when a temporary RPD is made, polishing occurs externally, and if there is an internal change of the piece, it will promote its maladaptation in the mouth. The unpolished side was marked with a permanent pen.

Experimental design

As there was only one variable under study, the types of resins, two experimental groups were formed, as shown in Table 1. Each experimental group had 10 block specimens for surface analysis and 10 bar specimens for mechanical testing (table 1). The sample size of this study was calculated based on the standard deviation of similar research, the study by Singh et al. [2], thus N=10 exceeds the sample power of 80.0% compared to maximums. The prepared specimens were stored in distilled water and after 24 hours the surface roughness analysis was initiated for the block specimens and the bar specimens followed in the oven aging.

Table 1. Experimental groups, description, surface roughness test, fracture resistance test, and polymerization.

Experimental groups	Description	Surface roughness test	Fracture resistance test	Polimerization
RAT	Thermopolymerizable Acrylic resin (conventional)	N= 10 especimen Block	N= 10 especimen Bar	Conventional
RTP	Thermoplastic resin (flexible)	N= 10 especimen Block	N= 10 especimen Bar	Injection

Surface roughness

Specimens were evaluated for mean surface roughness (Ra) using a contact roughness (Mitutoyo surftest SJ-400, Mitutoyo Corporation, Japan); with a spherical diamond tip, 0.5 mm in radius size, which moves at a speed of 0.5 mm/s. The tip was programmed to travel a distance of 4 mm (cut-off sampling length = 0.8 mm). Three readings were taken on each specimen, polished side. The measurements in longitudinal direction, counting 3 readings per specimen and the roughness value was obtained by the arithmetic mean of the readings in each specimen and on each side.

Aging

All study specimens were subjected to oven aging (FANEM, Orion Culture Greenhouse 502) for 60 days at 37°C±0.5°C in distilled water. After aging, the block specimens were subjected again to the surface roughness test and the bar specimens were subjected to the mechanical strength test.

Mechanical resistance

The three-point flexural strength test was performed in a universal testing machine EMIC model DL-1000 (EMIC DL 1000, São José dos Pinhais, Brazil). The bar specimens were submitted to tension until fracture, with the polished side facing down. The machine was programmed with a 100Kgf load cell, for a constant speed of 5mm/min, the flexural strength values were obtained in megapascals (Mpa) using the formula below (ISO 1567:1999).

$$\gamma = 3FD/2LH2$$

F - Maximum Force (N)

D - Distance on test device (50 mm)

L - Specimen length (65 mm)

H - Specimen thickness (3 mm)

Analysis of results

The results were tabulated and analyzed in Minitab software (version 16.1 for windows, Pennsylvania, USA), with a significance level of 5%. The surface roughness data were submitted to the Two-way Anova statistical test ($P < 0.05$), to evaluate the influence of materials and aging on topographic patterns. The mechanical strength data were submitted to the One-way Anova statistical test ($P < 0.05$), to identify the influence of the relationship between the supported stress and the materials until fracture. Tukey's Test was applied when a $P < 0.05$ was observed.

Qualitative analysis

Stereomicroscope images (Discovery V20, Zeiss, Gottingen, Germany) were taken of the surfaces of the resin materials as well as an image after the mechanical strength test.

RESULTS

The study data showed statistical difference between experimental groups. For roughness, the Two-way Anova Test identified that the resin type factor ($P = 0.000$) and the aging factor ($P = 0.000$) were statically significant, and also showed interaction ($P = 0.228$), as shown in table 2. The Thermopolymerizable acrylic resin had the lowest mean roughness values compared to the thermoplastic resin and showed no statistical difference after aging, according to Tukey's Test. The values of flexural strength, the thermopolymerizable acrylic resin was statistically superior to the thermoplastic resin ($P = 0.000$), according to the One-way Anova Test (table 3).

Table 2. Experimental groups (resin type and aging), Mean Ra in µm (Standard Deviation - SD) and Grouping*.

Experimental groups		Mean Ra in µm (SD)	Grouping *
Resin Type	Aging		
RAT	Dry	0.03477 (0.003916)	A
RAT	Aging	0.04283 (0.006962)	A
RTP	Dry	0.05860 (0.006560)	B
RTP	Aging	0.07200 (0.009080)	C

Note: * Tukey's test shows difference between groups with different letters.

Table 3. Experimental groups (Resin Type and Aging), Mean in Mpa (Standard Deviation - SD) and P-value*.

Experimental groups		Mean in Mpa (SD)	P-valor*
Resin Type	Aging		
RAT	Aging	44.85 (6.482)	0.000
RTP	Aging	27.22 (3.837)	

Note: * One-way Anova test is significant when $P < 0.05$.

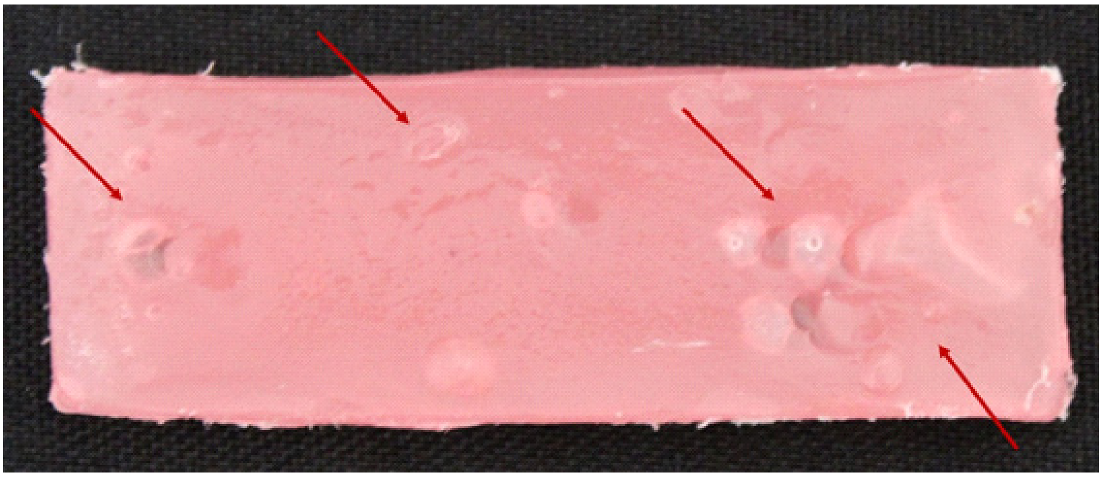

Figure 1. Defects and Pores in the thermoplastic resin specimens.

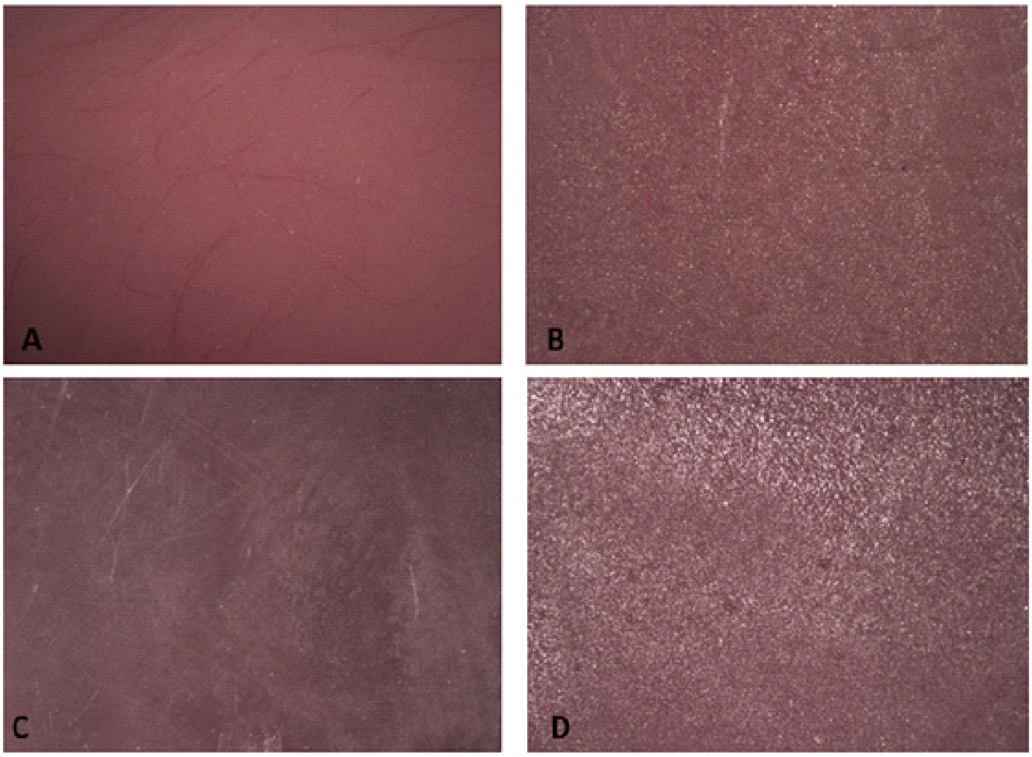

Figure 2. Polished and unpolished surface of the resins under study, A-RAT polished (15x magnification stereomicroscope image), B-RAT unpolished (15x magnification stereomicroscope image), C-RTP polished (12x magnification stereomicroscope image), D-RTP unpolished (12x magnification stereomicroscope image).

After polymerization of the thermoplastic resin, large amounts of defects and pores were identified in some specimens (figure 1). The polished and unpolished surface of the specimens for both resins, through stereomicroscope imaging, no surface changes are observed between the materials (figure 2). During the flexural strength test, the specimens of thermoplastic resin suffered deformation and did not return to the initial state, but no destructive fracture occurred as with the thermopolymerizable acrylic resin (figure 3).

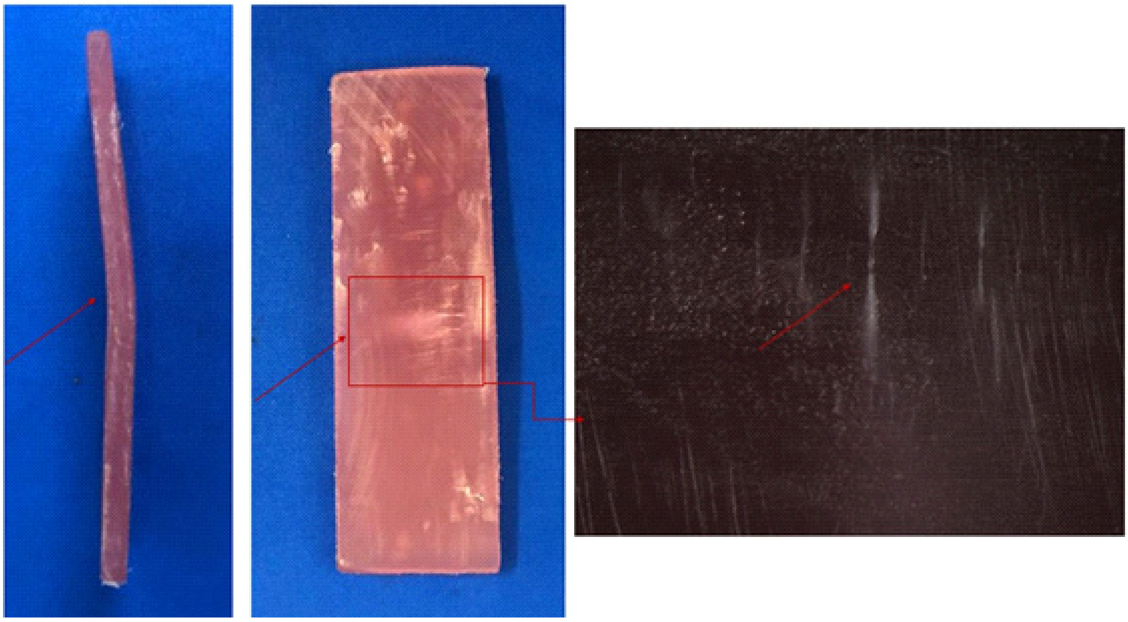

Figure 3. A) Bar specimens of the RTP group after the flexural strength test, the arrow shows the permanent change of the specimen; B) Arrow points area where the chisel was positioned; C) Stereomicroscope image (13x magnification) shows the stress area (arrow) suffered by the specimens during the mechanical test.

DISCUSSION

Replacing lost teeth with RPD by present a considerable demand in the coming years, therefore, it is essential to promote health and training of professionals involved in the treatment, as well as research that shows the performance of alternative materials in the long term. Therefore, it is necessary to study dental materials, their physical and chemical characteristics, and how much they influence, beneficially or not, the final product. The selection of the right material largely depends on the scenario, in which it is to be used, and erroneous selection can lead to failure of the prosthetic rehabilitation [2]. Currently, there is not enough information about RPD without metal clampless and with thermoplastic resin. Professional should be well aware of the properties of these resins, in order to choose a suitable resin for each patient [7].

The research findings indicate that the thermoplastic resin after aging showed higher mean roughness values, while the thermopolymerizable resin showed lower roughness values and did not undergo the action of aging. These results are in agreement with the literature surveyed [2,8,9]. Importantly, a study found that immersion of both resins in red wine and instant coffee did not significantly alter surface roughness values [9]. As for biofilm growth, polyamide resin (flexible) showed greater growth of Candida spp. compared to PMMA (conventional), and its surface roughness was standardized (0.34 ± 0.02 μm) [10]. In the study by Abuzar et al. [8], the surface roughness of polyamide is smoothed after mechanical lathe polishing, and is within the clinically accepted limit of 0.2 μm.

The flexural strength of conventional resin was statistically superior to flexible resin, and the literature shows similar [5,6,11-13] and distinct [2,14] results, i.e., higher mechanical strength of flexible resins. The mechanical performance of resins is affected by material properties, polymerization technique, and aging [7,14]. Different types of artificial aging have tested properties of these resins and proved to be significant for flexural strength values [7,9,11-13,15]. Perhaps, the reason for the low mechanical strength of the flexible resin is due to the high number of defects and pores on the surface of the specimens by the injection technique. Thus, it promoted an increase in water sorption since the bars were aged for 60 days in distilled water. According to Hamanaka et al. [15], water sorption significantly reduced the mechanical strength and modulus of elasticity of Polyamide (flexible) and PMMA (conventional).

An important point to be registered is that fracture analysis, after the flexural strength test, has been little addressed in the literature [7,12]. The present research observed that all thermoplastic resin specimens did not fracture after the mechanical test, a situation that corroborates other published studies [7,12]. In contrast, several studies do not state the fracture condition of the specimens [2,5,11,13-15]. The fracture behavior of a material is relevant to the dental decision in the treatment of his patient [12]. The study by Hamanaka et al. [7] did not obtain any fractured specimens (Thermopolymerizable resin and thermoplastic resins), however the methodology applied was deflection observed through mechanical cycling (5,000 cycles). In the research of Ucar et al. [12] all polyamide specimens (flexible) did not fracture during the flexural test and showed a high risk of deflection, corroborating the findings of this study.

So why are flexible resins not extensively applied in prosthetics in daily practice? Since this material does not present fracture after mechanical testing. This behavior is due to the plastic deformation property of these resins, when it exceeds the proportional limit there will be a permanent change and the high or similar, to conventional resin, impact resistance. Therefore, this behavior is unacceptable for denture base materials, as it interferes in the retention and stability of the Removable Partial Denture without clamp [7]. Denture materials must have a high proportional limit to avoid permanent deformation, low elasticity modulus to avoid stress of insertion and removal of the prosthesis, and high impact resistance [7]. The flexibility of these resins is favorable for clamps, but not for making a larger connector, as there is a need for rigidity [12].

Flexible resins are an option for prosthetic materials for individuals allergic to polymethylmethacrylate or cobalt chromium, in cases of constant fractures of conventional prostheses, in patients with reduced manual dexterity, and also in conditions of torus, cleft palate or knife-edge ridge [3,4]. Based on the roughness and mechanical strength results of this research, extrapolating to clinical practice the use of flexible resin as a material should be performed with limitations, since there is an increase in surface roughness after aging, a factor that favors biofilm accumulation. Besides the low flexural strength, which although it does not promote destructive fracture of the material, there is permanent deformation, which may interfere with retention and stability of the prosthesis? Considering this material as a provisional for partially edentulous arches, perhaps it could be adopted, although studies with more robust scientific evidence are still needed.

Among the limitations of the study was the presence of defects in the thermoplastic resin specimens due to the injection technique, thereby increasing roughness and reducing flexural strength. It seems that this situation occurred due to the technique being indicated for making prostheses with less thickness, the use of geometric specimens in the research made the polymerization of flexible resins more difficult. New studies should seek to evaluate the mechanical aging of these resins and adopt specimens that are close to the real patterns of the prostheses in order to evaluate the survival of this material. Try to test different possibilities of polishing, adopted in the dental office, in order to reduce surface roughness. Randomized clinical studies on retention, stability and patient satisfaction with the use of thermoplastic resin prostheses are also desirable. Thus, the null hypothesis of the study was rejected and the alternative hypothesis was accepted. Because there was a statistically significant difference between different materials for making temporary partial dentures, regarding the values of surface roughness and mechanical strength.

CONCLUSION

Thermopolymerized acrylic resin showed lower surface roughness values and higher flexural strength values compared to thermoplastic resin. The effect of aging showed no change in mean roughness values for the conventional resin, but was significant for the flexible resin.

Collaborators

LO Almeida, analysis, data interpretation and article writing. MTV Grangeiro, conception and design, analysis and data interpretation. VMG Figueiredo, conception and design, analysis and data interpretation and article writing.

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