UNIVERSIDADE FEDERAL DE JUIZ DE FORA
CAMPUS GOVERNADOR VALADARES
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS APLICADAS Ã SAÚDE

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Avaliação das propriedades ópticas e superficiais de diferentes resinas utilizadas para base de prótese total com ou sem o uso do glaze

Governador Valadares
2023

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Dissertação apresentada ao Programa de Pós-Graduação em Ciências Aplicadas à Saúde, da Universidade Federal de Juiz de Fora, Campus Governador Valadares, como requisito parcial à obtenção do título de Mestre em Ciências Aplicadas à Saúde, área de concentração Biociências.

Orientador: Prof. Dr. Cleidiel Aparecido Araújo Lemos

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2023

Bernardes Marçal, Ismenia Edwirges .
Avaliação das propriedades ópticas e superficiais de diferentes resinas utilizadas para base de prótese total com ou sem o uso do glaze / Ismenia Edwirges Bernardes Marçal. -- 2023.
67 p.

Orientador: Cleidiel Aparecido Araújo Lemos
Dissertação (mestrado acadêmico) - Universidade Federal de Juiz de Fora, Campus Avançado de Governador Valadares, Instituto de Ciências da Vida - ICV. Programa de Pós-Graduação em Ciências Aplicadas à Saúde, 2023.

1. Prótese Total. 2. Propriedade de Superfície. 3. PMMA. I. Araújo Lemos, Cleidiel Aparecido , orient. II. Título.

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Aprovada em 26 de outubro de 2023.

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Juiz de Fora, 06/10/2023.

AGRADECIMENTOS

À Deus autor da vida, por sempre me dar força, luz, fé e perseverança.

Aos meus pais, José e Maria, e ao meu irmão, Israel, por sempre me incentivarem, impulsionando a seguir meus sonhos.

Ao meu marido por todo amor e carinho, pela força para concluir a pesquisa, parceria e incentivo sempre.

Ao meu orientador Prof. Dr. Cleidiel Aparecido Araújo Lemos, pela orientação, dedicação, apoio para que esse projeto concretizasse.

Aos meus amigos pelo incentivo em iniciar esse projeto, e por todo apoio e carinho ao longo dessa caminhada.

À instituição UFJF-GV, a qual me orgulho em fazer parte desde o início de sua implementação, e agora como pós-graduanda e também docente, é muito gratificante fazer parte dessa equipe.

São muitos desafios e obstáculos, mas o foco sempre em um ensino de qualidade e incentivo a ciência, são responsáveis não só pela formação de profissionais de excelência como também a realização de inúmeros sonhos. Serei eternamente grata!

RESUMO

As próteses totais removíveis são a opção menos invasiva e mais econômica para a reabilitação protética, são fabricadas usando resina acrílica, como polimetilmetacrilato (PMMA), devido às suas propriedades físicas e estéticas. O objetivo desse estudo foi avaliar as diferenças de microdureza, rugosidade, características ópticas, de diferentes resinas utilizadas para confecção de bases de próteses totais em relação ao tipo de acabamento (polimento ou polimento e glaze) antes e depois da termociclagem(TC). Foram considerados quatro tipos de resinas, de acordo com o método de fabricação, sendo: convencional TC (banho-maria) ou (micro-ondas); PMMA fresada, e resina impressa 3D. Foram confeccionadas um total de 160 amostras, de diâmetro 10 mm e 3 mm de espessura. As variáveis das resinas foram: com polimento/com glaze (CP/CG); com polimento/sem glaze (CP/SG); sem polimento/com glaze (SP/CG); sem polimento/sem glaze (SP/SG). Foi considerada a análise de variância a dois fatores utilizando o programa JAMOVI. Os maiores valores de alteração de cor (ΔE) foram encontrados na resina 3D para os grupos que foram realizados polimentos mecânicos (CP/CG; CP/SG. Antes da TC o grupo com SP/SG apresentou os maiores valores de rugosidade com diferença significativa para todos os demais polimentos, independentemente do tipo de resina ($P<0,05$). Na análise de microdureza antes da TC pode ser observado menores valores de microdureza para as resinas impressas 3D ($p<0,001$),

principalmente para o grupo SP/CG. Conclui-se que a ausência do polimento mecânico contribuiu para maior alteração de cor e rugosidade. Os tipos de polimento influenciaram as propriedades de microdureza em relação aos diferentes tipos de resina, sendo que a resina impressa 3D apresentou a maior variabilidade antes e após a TC.

Palavras-chave: PMMA. Cor. Propriedades de superfície. Prótese Total.

ABSTRACT

Removable complete dentures are the less invasive and more economical option for prosthetic rehabilitation, and they are manufactured using acrylic resin, such as polymethyl methacrylate (PMMA), due to its physical and aesthetic properties. The objective of this study was to evaluate the differences in microhardness, roughness, optical characteristics, of different resins used for the fabrication of complete denture bases in relation to the type of finishing (polishing or polishing and glaze) before and after thermocycling (TC). Four types of resins were considered based on the manufacturing method: conventional TC (water bath) or (microwave); milled PMMA, and 3D printed resin. A total of 160 samples were fabricated, with a diameter of 10 mm and a thickness of 3 mm. The resin variables were: with polishing/with glaze (P/G); with polishing/without glaze (P/NG); without polishing/with glaze (NP/G). Without polishing/without glaze (NP/NG). A two-factor analysis of variance was performed using the JAMOVI program. The highest color change values (ΔE) were found in the 3D resin for the groups that underwent mechanical polishing (P/G; P/NG). Before TC, the SP/SG group exhibited the highest roughness values with a significant difference compared to all other polishing methods, regardless of resin type ($P < 0.05$).In the microhardness analysis before TC, lower microhardness values were observed for 3D printed resins ($p < 0.001$), especially for the NP/G group. It is concluded that the absence of mechanical polishing contributed to greater color

change and roughness. The types of polishing influenced the microhardness properties in relation to the different resin types, with 3D printed resin showing the highest variability before and after TC.

Keywords: PMMA. Color. Surface Properties. Denture.

LISTA DE SIGLAS

CP/CG	Com Polimento/Com Glaze
CP/SG	Com Polimento/Sem Glaze
SP/CG	Sem Polimento/Com Glaze
SP/SG	Sem Polimento/Sem Glaze
PMMA	Polimetilmetacrilato
TC	Termociclagem
TC	Thermocycling
BM	Banho Maria
MC	Microondas
MC	Microwave
BM	Water Bath
P/G	With Polishing/With Glaze
NP/G	Without Polishing/With Glaze
P/NG	With Polishing/Without Glaze
NP/NG	Without Polishing/Without Glaze

SUMÁRIO

1 INTRODUÇÃO

Segundo o IBGE [1] a proporção de idosos em 2022 no Brasil acima de 65 anosé de 10,49%(IBGE) correspondendo a 37,7 milhões de pessoas idosas,[2]. Embora tenha sido observado um aumento nas políticas de saúde pública relativas a prevenção de doenças orais, segundo estimativas da OMS conduzida pela Fiocruz, 14,4% dos brasileiros perderam todos os dentes na faixa de idade entre 50 e 74 anos, em decorrência disso o número de indivíduos necessitando de próteses totais cresce a cada ano, [3].

As próteses totais removíveis são a opção menos invasiva e mais econômica para a reabilitação protética de pacientes totalmente desdentados,[4] . A reabilitação oral com próteses dentárias exerce uma grande influência no cotidiano das pessoas e tem enormes implicações sociais [5]. Além disso promovem um equilíbrio das funções mastigatórias, deglutição, fala, estética e uma melhora da autoestima do paciente,[6].

As próteses dentárias removíveis convencionais geralmente são fabricadas usando resina acrílica, como polimetilmetacrilato (PMMA), devido às suas propriedades físicas e estéticas, além de manuseio favorável,[7].Esse material apresenta algumas qualidades tais como: biocompatibilidade, estabilidade, impermeabilidade, confiabilidade, relativa facilidade de manipulação, baixa toxicidade e ausência de irritação aos tecidos bucais, que logo foram aproveitadas e incorporadas ,[8]. Entretanto, apesar dessas características, o PMMA pode apresentar alguns problemas relacionados a fadiga flexural sob repetidas forças mastigatórias e sua fragilidade, que causa principalmente o fracasso das próteses,[9]. Além disso, outras limitações tais como baixa condutividade térmica, alto coeficiente de expansão térmica, fragilidade, falta de tenacidade e resistência, e um baixo módulo de elasticidade, podem criar algumas falhas durante a função,[10].

Em alternativa ao tratamento convencional, nos últimos anos, as tecnologias de desenho assistido por computador e fabricação assistida por computador (CAD-CAM) permitiram a fabricação de próteses removíveis, bases de registro e sobredentaduras implanto-suportadas através de procedimentos subtrativos (fresamento) ou aditivos (impressão 3D) [11].

Antes da introdução da tecnologia CAD/CAM em próteses removíveis, a

congruência entre a base da prótese e os tecidos de suporte, era dificultada pela possibilidade da contração de polimerização da resina [11]. Essas distorções na base da prótese tem um impacto negativo no ajuste e retenção de próteses totais removíveis. Na fabricação CAD/CAM, por outro lado, pelo processo de fabricação subtrativo as bases da prótese são fresadas a partir de discos de resina acrílica totalmente polimerizados, através de um controle rigoroso das condições de pressão e temperatura durante a polimerização e, portanto, não estão mais sujeitos a fenômenos de encolhimento ou distorção [12 -13].

Neste sentido, sabe que o polimento é um dos principais fatores que podem influenciar nas características físicas e ópticas superficiais desses materiais [14-15]. A ausência ou dificuldade do polimento, não interfere somente nas características extrínsecas desses materiais, como também pode aumentar a propensão de complicações biológicas como a estomatite devido ao acúmulo de microrganismos,[16]. Neste sentido, polimentos mecânicos, químicos ou até mesmo o emprego de selantes/glazes podem ser indicados para garantir que a base apresente uma favorável lisura superficial,[17-18 -19].

Vários selantes têm sido utilizados como camada de revestimento de próteses totais, proporcionando uma superfície mais lisa e brilhante e reduzindo o acúmulo de placa, devido a hidrofilicidade e viscosidade muito baixa da superfície daprótese [12].

Recentes trabalhos têm relatado que a aplicação de uma camada de revestimento na superfície de bases de dentaduras tem aumentado as propriedades mecânicas e dureza [20], e contribui no aumento de vida útil da prótese, retardando o progresso de rugosidade e da perda da resina após procedimentos de mastigação e limpeza,[21]. Em contrapartida, alguns autores destacaram superioridade dos procedimentos de polimentos convencionais em relação a utilização do revestimento,[7].

Dessa forma, não existe um consenso na literatura a respeito da influênciado uso da camada de revestimento em relação ao protocolo de polimento convencional nas características superficiais físicas e ópticas de resinas para base de dentaduras. Essas características apresentam relevância principalmente se aplicado em relação a avaliação das diferentes possibilidades reabilitadoras, ou seja, pelo método convencional e CAD-CAM através de manufatura aditiva ou subtrativa,[18].

2 ARTIGO CIENTÍFICO

Artigo Científico enviado para publicação no periódico Elsevier CAPES A1.A estruturação do artigo baseou-se nas instruções aos autores preconizados pelo periódico (ANEXO A).

Evaluation of color change, surface roughness and microhardness of different denture base resins with and without coating

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Acknowledgements

Scholarship of master's degree for one reviewer (I.E.B.M.) by Coordination for the Improvement of higher Education Personnel (CAPES) – Finance Code 001.

ABSTRACT

Removable complete dentures are the least invasive and most economical option for prosthetic rehabilitation, and they are manufactured using acrylic resin, such as polymethyl methacrylate (PMMA), due to its physical and aesthetic properties. The objective of this study was to evaluate differences in microhardness, roughness, optical characteristics, solubility, and sorption of different resins used in the fabrication of complete denture bases in relation to the type of finishing (polishing or polishing and glaze) before and after thermocycling (TC). Methods: Four types of resins were considered based on the manufacturing method, namely: conventional heat-polymerized (water bath) or (microwave); milled PMMA, and 3D printed resin. A total of 160 samples were fabricated, with a diameter of 10 mm and a thickness of 3 mm. The resin variables were: with polishing/with glaze (P/G); with polishing/without glaze (P/NG); without polishing/with glaze (NP/G); without polishing/without glaze (NP/NG). Results: A two-factor analysis of variance was conducted using the JAMOVI program. The highest color change values (ΔE) were found in the 3D resin for the groups that underwent mechanical polishing (P/G; P/NG). For sorption and solubility before and after TC, no differences were observed among the evaluated resins. In the microhardness analysis before TC, lower microhardness values were observed for 3D printed resins ($p < 0.001$). Significance: This study demonstrated that the absence of mechanical polishing contributed to greater color change and roughness, and that the types of polishing influenced microhardness properties concerning the different resin types.

Keywords: PMMA. Color. Surface Properties. Denture.

1. INTRODUCTION

Polymethyl methacrylate (PMMA) is a polymer that is most commonly used in dental laboratories for the fabrication of dentures for fully edentulous patients [1]. PMMA has gained popularity for various dental applications due to its unique properties, such as excellent dimensional stability in oral environments, low cost, lightweight nature, acceptable aesthetics, and ease of repair [2]. Additionally, it has a low density, cost-effectiveness [1] and excellent transparency, which seamlessly integrate with the oral cavity without discomfort [2].

However, there are many concerns related to the use of PMMA, including denture fractures caused by sorption and water impact, as well as decreased flexural strength, porosity, and polymerization shrinkage [3]. Traditionally, acrylic resins have been flask-pressed when they reach the plastic stage and then immersed in a heated water bath or microwave to allow for the thermopolymerization of the monomer [4].

In recent years, computer-aided design and computer-aided manufacturing (CAD-CAM) technology have enabled the fabrication of removable dentures, registration bases, and implant-supported overdentures using subtractive (milling) or additive (3D printing) procedures. Compared to traditional workflows, digital workflow offers several advantages such as reduced clinical time and cost, increased accuracy, and maintenance of digital treatment records [5-6].

Recent systematic reviews have demonstrated superiority, particularly in the mechanical properties of resin bases obtained through CAD/CAM technology, whether by subtractive or additive manufacturing, compared to conventional PMMA resins [7-8]. However, when it comes to physical and optical surface properties, they may be less explored, considering the different rehabilitative possibilities for complete denture bases, especially when comparing additive manufacturing to traditional milling.

Goodacre et al. [5] and Goodacre et al. [6] reported that despitethe lower flexural strength and lower fracture resistance of 3D printed dentures compared to milled ones, they still offer numerous advantages over conventionally milled and processed dentures. Furthermore, they emphasized that in the coming years, additive manufacturing is likely to play a more significant role, with increased knowledge about materials and techniques employed. Thus, the authors recommend future research that addresses remaining questions regarding the various materials considered for denture bases.

Another factor that can directly affect the properties of materials for denture bases is related to polishing characteristics [8,9], as it directly influences the extrinsic characteristics of the materials, which can lead to various complications [10].

In clinical practice, it is common to use mechanical polishing of the external surface of denture bases. However, some authors consider the use of surface glazes with the intention of achieving a smoother surface [11-13], as well as improving mechanical properties or delaying the process of roughening [14]. However, there is no consensus on this statement, as in the long term, the glaze layer could be affected by the action of foods, fluids, and oral temperature, and consequently, exhibit inferior characteristics compared to conventional mechanical polishing procedures [15].

Therefore, due to the lack of consensus regarding its use, especially when compared to the utilization of different resins available for denture bases, this study aims to compare the variables of microhardness, solubility, sorption, roughness, and optical characteristics of different resins for complete denture bases (conventional resins: heated in water bath and microwave; milled resin; 3D printed resin) in relation to different types of procedures Polishing (mechanical polishing/no mechanical polishing; with or without glazing) before and after thermocycling of the samples. The null

hypothesis of the article is that the resins or the type of polishing do not affect the properties of color change, surface roughness, and microhardness.

2. METHODOLOGY

2.1 EXPERIMENTAL DESIGN

For the execution of this study, four types of resins for denture base was considered, according to the manufacturing method, namely: conventional heat-polymerized (water bath) and (microwave); milled PMMA (CAD/CAM), and 3D printed resin. Thus, a total of 160 samples was fabricated with a diameter of 10 mm and a thickness of 3 mm, measured using a digital caliper, divided among the evaluated groups, totaling 40 samples for each resin, 10 for each group (Table 1).

2.2 SAMPLE ACQUISITION

For the preparation of conventional samples, metal molds with the dimensions of the samples were placed inside plastic flasks (Vipi – STG Ltda), positioned between glass plates on special type IV gypsum (Durone, Dentsply Ltda). The resins were handled according to the manufacturer's recommendations (Clássico; Clássico) and inserted into the molds. These were kept under a load of 12.3 kN in a hydraulic press and left on a bench for 30 minutes [16]. The samples from the conventional method was polymerized in a water bath for 60 minutes in boiling water (100°C).

On the other hand, the samples that was milled and 3D printed was initially designed using a design software program, Exocad Valletta, Darmstadt, Germany, version 2.2.6654 2017. The CAM software version (milling and block path creation) will be Exocad Plovdiv CAM, Darmstadt, Germany, version 3.8.31803. For milling the pink PMMA blocks (Evolux PMMA GUM – Gengiva Blue Dent ©), they was milled using a milling machine (Amann Girrbach Ceramill Motion 2 DNA Herrschaftswiesen, Koblach,

Austria) to obtain the milled samples with dimensions similar to the conventional samples. As for the liquid PMMA resin (Smart Print Bio Denture DLP 3D Printer Resin) in pink color, it was used for printing on a stereolithographic printer with digital light processing technology (MoonRay Model S; VertySystem) to obtain the 3D printed samples at a 45º orientation, with the same diameter dimensions similar to the conventional samples.

After obtaining the cylinders of the milled and 3D printed samples, the samples were subjected to a precision cutter (Isomet 1000, Buehler, Plymouth, Minnesota, USA), and they were sectioned using diamond blades (Extec High Concentration, Extec, Enfield, CT, USA) with cooling to obtain samples with a thickness similar to the conventional samples.

2.3 POLISHING OF THE SAMPLES

After the fabrication of the samples, the first evaluated group will consist of samples from the negative control group that will not undergo any type of treatment (without mechanical polishing and without glazing). The second group was the group without mechanical polishing with glaze. For this, the Megaseal glaze (MEGADENTA Dentalprodukte GmbH, Germany) was applied according to the manufacturer's recommendation, with a final uniform layer of glaze applied with the aid of a soft brush in a single direction. The samples were allowed to sit for 20 seconds for the action of the glaze before polymerization, and then the samples were polymerized for 180 seconds with the help of a laboratory stroboscopic photopolymerized

In Group 3, the samples will undergo metallographic finishing and standardized polishing using a polisher (Aropol E; Arotec) with the assistance of silicon carbide papers (#240, #400, #600, and #1200) for 20 seconds on each surface [16-17]. Subsequently, a finishing polish was performed using a felt brush with Universal

Polishing Paste - Ivoclar Vivadent. In Group 4, the same steps for finishing and mechanical polishing used for Group 3 was considered, with the addition of the application of glaze as described for Group 2. After the completion of the processing, each denture was immersed in an ultrasonic bath for 5 minutes to remove possible debris [9]. Following the procedure, each denture was placed in distilled water for 24 hours [18].

2.4 ASSESSMENT OF SURFACE ROUGHNESS

The surface roughness profile for each specimen was measured after polishing using a surface roughness measuring instrument (TR200, Digimess, São Paulo, SP, Brazil). The measurement was conducted on each individual specimen, and the diamond-tipped stylus has a 5 μm radius at a constant speed of 0.25 mm/s with a force of 4 mN. The cutoff value was set at 0.08 mm (Gaussian filter). Ra is the average roughness, which is determined by the arithmetic mean of the absolute values of the ordinate values in the roughness profile. Three readings were taken on each surface sample at equidistant positions, rotating the sample by 90th. The average of these three Ra measurements was calculated as the surface roughness value of the specimen [19].

2.5 COLOR CHANGE

The optical properties of the specimens was evaluated using a spectrophotometer (UV-2450; Shimadzu, Kyoto, Japan). The changes were calculated using the CIEDE2000 (ΔE00) as established by the Commission Internationale de l'Eclairage (CIE). Color measurements in the CIEDE2000 color system consist of three components representing the black-white brightness (L*) and the green-red (a*) and blue-yellow (b*) color dimensions, with the L* axis perpendicular to the a* and b* axes. The device emits a source of visible light (400 to 700 nm) onto the object and measures the reflection of this spectrum. The L*, a*, b* values of each sample were measured

before and after immersion. The ∆E00 values were calculated using the formula: ∆E00 = (ΔL/KL × SL) + (ΔC/KC × SC) + (ΔH/KH × SH) × SC)² + (ΔH/KH × SH)² + RT × (ΔC/KC × SC) × (ΔH/KH × SH)/0.5, where ΔL*, ΔC*, and ΔH* are the differences in lightness, chroma, and hue between two specimens, and RT (rotation function) is a function that explains the interaction between differences in chroma and hue in the blue region. SL, SC, and SH are weighting functions for the luminance, chroma, and hue components, respectively. KL, KC, and KH are parametric factors according to different viewing conditions, which were defined as 1 [20].

2.6 MICROHARDNESS

Microhardness measurements was carried out using a microhardness tester (HMV II; Shimadzu Corporation, Kyoto, Japan) with a Vickers indenter (HV) at a load of 50 g for a dwell time of 10 s, [21]. Five indentations were made on each specimen, with a minimum distance of 100 μm between them, and the average HV value was obtained [19].

2.7 THERMOCYCLING

After the initial analyses, all samples were subjected to thermocycling (Model MSCT-3, Convel) in distilled water with alternating baths of 30 seconds at temperatures of 5±1°C and 55±1°C (70 seconds per cycle; dwell time: 30 seconds; transfer time: 5 seconds). The thermocycling, under the conditions presented, represents every 5,000 cycles, [23]. After completing thermocycling, the samples were measured again in all previously described analyses.

2.8 STATISTICAL ANALYSIS

After measuring each of the specific tests, the data were subjected to normality analysis (Shapiro-Wilk) to determine the most suitable test for the analyses. Two-way analysis of variance (ANOVA) was considered with the intention of examining the

interaction between resins and the use of glaze for each of the simulated tests. The data were subjected to statistical analysis using JAMOVI Version 2.2 (https://www.jamovi.org).

3. RESULTS

The highest data of color change (ΔE) were found in the 3D printed resin with significant differences when compared to water bath, microwave, and CAD/CAM resins for P/G and P/NG groups. In the NP/G group, the microwave resins showed lower color change in comparison with CAD/CAM (P = 0,03) and 3D printed resins (P = 0,002). In the NP/NG group CAD/CAM showed the highest color change with a significant difference with water bath and microwave resins (P<0,001). No significant differences were observed between the water bath and microwave groups (P = 0.762). Regarding the polishing, no significant differences were observed between P/G with P/NG (P = 0.313), and NP/G (P = 0.051). In addition, the groups with greater changes in NP/G and NP/NG did not differ from each other (P = 0.815). No difference was observed for color change between the polishings within the same denture base resin, except for the CAD/CAM resins in the SP/SG group that showed significant differences in comparison with CP/CG and CP/SG groups (P<0.001), however, without difference in comparison to the SP/CG (P=0.13) (Table 2).

The surface roughness was evaluated obtaining the highest values before thermocycling for the NP/NG group, with a significant difference compared to all other polishings, regardless of the resin type (P<0.05). For the microwave resin group, significant difference was observed for the NP/G in comparison with P/G (P < 0.001) and P/NG (P < 0.001) groups. No significant differences were observed for the evaluated resins, regardless of polishing, except for the NP/NG control, where 3D resin

roughness values were significantly higher than those of the water bath resin ($P < 0.001$). After the thermocycling analysis, no significant differences were observed between the evaluated resins, regardless of the type of polishing ($P > 0.05$). The lowest values of surface roughness were observed for the P/NG group, with significant differences in comparison to groups that did not undergo mechanical polishing (NP/G and NP/NG) ($P<0.001$) (Table 3).

The results obtained for microhardness before thermocycling indicated lower microhardness values for 3D printed resins, especially for the NP/G group ($P<0.001$). The highest values of microhardness were observed for the NP/NG group, with no differences between the evaluated resins ($P>0.05$). In the analysis after thermocycling, lower microhardness values were observed for the 3D printed resins, with significant differences for other resins for almost all polishing groups ($P<0.05$), except for the P/G group, which showed similarity to the water bath ($P = 0.066$) and CAD/CAM ($P = 0.06$) resins. There was no difference in microhardness between the other resins independent of the type of polishing evaluated ($P>0.05$). The polishing methods did not influence the microhardness of the water bath, microwave, and CAD/CAM resins ($P > 0.05$). On the other hand, in the group of 3D printed resins, the P/G and NP/NG groups presented higher microhardness values compared to the P/NG and NP/G groups ($P < 0.05$) (Table 4).

4. DISCUSSION

The null hypothesis evaluated was rejected, because significant differences were observed in color change, surface roughness, and microhardness between denture base resins or polishing techniques. According to Sarac et al. [24], the surface coating with sealing agents of the denture bases in the complete dentures is recommended to

improve the surface smoothness by filling in micro-fissures and micro-defects and can be considered an alternative to conventional polishing. However, surface sealants have some limitations, such as low abrasion resistance, poor adhesion to the underlying material, and poor surface quality resulting from spreading failure that likely depends on high viscosity. This can compromise the smoothness properties of the base over time in action in oral function. In the results of surface roughness, it was possible to observe this phenomenon. Before TC similar results were observed for almost groups, except NP/NG (which was expected due to be considered a negative control). The NP/NG group showed the lowest values of surface roughness before and after TC compared to the other groups. According to Seabra et al. [25], polishing increased the smoothness of acrylic resin, controlling the increase in surface roughness caused by experimental conditions. Comparing with the study by Melo et al. [9], where the results demonstrate the ability of the polishing protocol to maintain the smoothness of acrylic resin at desirable levels, controlling the progressive deleterious effect of the tested factors.

However, after TC, in addition to the negative control, the groups that had glaze (P/G and NP/G) significantly increased roughness values compared to the mechanical polishing group without glaze (P/NG). this proves the influence of the oral environment on the surface of the glaze layer. These results are partially in accordance with the study by Atalay et al. [13], which used CAD/CAM samples and compared different surface treatments before and after TC, discovering that there was a significant interaction between the material and surface treatment. Conventional/mechanical laboratory polishing, in general, resulted in lower values of surface roughness.

Regarding the denture base resins, after TC, no significant differences were observed, regardless of the type of polishing. These results agree with a previous study published

by Koroglu et al. [26], that did not show significant differences between the surface roughness (Ra) values of all the prosthesis base materials tested. However, our results showed a difference compared to the previous that found significantly lower roughness for CAD-CAM PMMA compared to conventional PMMA [27]. This could be justified by the interaction of the polishing variable tested in our study.

Regarding the color change, the highest values were observed for the 3D resins base (except for the negative control group the CAD/CAM denture base showed the highest value). Although normally, the color change can be attributed to a porous surface [28], which justifies the highest values for NP/NG groups, independent of resin; however, no significant difference was attributed to the surface roughness of evaluated resins. Therefore, the possible difference should be attributed to other factors. One factor that should be considered is higher water sorption during TC for 3D printed resins. This could contribute to degrading 3D printed resins and enhance the attachment of pigments [29]. In addition, other factors that could contribute to this difference is related to the composition of the photopolymerizable resin material, the 3D printer's polymerization mechanism, and the surface characteristics (porosities and degree of polymerization) of 3D printed dental prostheses [30].

Regarding the polishing techniques, no significant differences were observed for the color change, independent of the resin evaluated, except for the control negative (NP/NG) of CAD/CAM resin. The absence of difference in the polishing techniques confirms that the color change is not only dependent on surface roughness, since significant differences in polishing groups were observed. The results should be attributed to the use of only 5,000 cycles. However, this number of thermal cycles (5º C and 55º C water) were applied to materials that serve as the base for prostheses to simulate 5 years of temperature changes in the oral environment [31-32]. Another

factor that could influenced is the fact of the nonuse of colorant agents (coffee, wine, juice, and others) in the thermocycling, which could increase the color change [28-29].

In the microhardness analysis before thermocycling, lower values were observed for 3D printed resins, with $p < 0.01$, except for NP/NG group. In the literature, there is no consensus about the microhardness between different denture base materials. Ellakany et al. [33] compared conventional resins with 3D resins and different manufacturing methods, and the result was that milled resins exhibited higher hardness than conventional ones. Conversely, other studies by Al-Qahtani et al.[34] and Digholkar et al. [35] reported higher hardness for 3D printed resins compared to conventional and milled resins.

In the microhardness analysis after thermocycling, lower values of microhardness were observed for 3D printed resins, with significant differences for all groups ($P<0.05$), except for the P/G group in which 3D printed resins showed similarity to heat-cured water bath ($P = 0.066$) and CAD/CAM ($P = 0.06$) resins. This partially agrees with Atay et al. [14], where different surface treatments (polishing and glaze application) were performed for PMMA resins.

After TC, with the exception of 3D printed resin, all other resins did not show the difference between the polishing techniques. The groups that had glaze application showed similar microhardness values for P/G and NP/G, and they remained as intermediate values compared to the P/NG and NP/NG groups, suggesting that the glaze forms a film that increases surface smoothness because the microhardness values were not very high or very low.

Materials for dental prosthesis bases have traditionally been polished with pre-polishing using water and pumice, followed by fine polishing with polishing paste or

aluminum oxide particles containing polishing liquids to reduce surface roughness to a minimum level,[26].

According to the results of the study by Giti et al. [22], dentists should take into consideration the differences in mechanical characteristics between conventional materials and 3D-printed materials used for denture base construction. Further improvements in the properties of 3D-printed resin materials through composition modification or reinforcement are still necessary. The proper selection of post-curing methods could also be an option for improvement.

The present study has limitations as it is an in vitro study that did not fully simulate in vivo conditions. Additionally, for the samples that had glaze applied, the brush left some markings, which did not leave the sample surface completely smooth.

5. CONCLUSION

It is concluded that 3D printed resins showed highest color change a lower microhardness in comparison with other denture base resins. No difference in the surface roughness was observed between the evaluated denture base resins. However, the absence of mechanical polishing contributes to the increase of surface roughness, but not affect the color change. The types of polishing influenced the microhardness properties in relation to the different resin types, with 3D printed resin showing the highest variability before and after TC.

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TABLES

Table 1. Experimental design of the groups evaluated.

Resins	Polishing Techniques	Number of samples
Heat-polymerized acrylic resin (Classico - Clássico Artigos Odontológicos)	Mechanical Polishing with Glaze (P/G)	10
	Mechanical Polishing without Glaze (P/NG)	10
	Without Mechanical Polishing and Glaze (NP/G)	10
	Without Mechanical Polishing and without Glaze (NP/NG)	10
Heat-polymerized acrylic resin (Onda Cryl – Clássico Artigos Odontológicos)	Mechanical Polishing with Glaze (P/G)	10
	Mechanical Polishing without Glaze (P/NG)	10
	Without Mechanical Polishing and Glaze (NP/G)	10
	Without Mechanical Polishing and without Glaze (NP/NG)	10
Milled CAD/CAM denture base (Evolux PMMA GUM – Blue Dent)	Mechanical Polishing with Glaze (P/G)	10
	Mechanical Polishing without Glaze (P/NG)	10
	Without Mechanical Polishing and Glaze (NP/G)	10
	Without Mechanical Polishing and without Glaze (NP/NG)	10
3D printed resin (Resina priZma 3D – Bio Denture)	Mechanical Polishing with Glaze (P/G)	10
	Mechanical Polishing without Glaze (P/NG)	10
	Without Mechanical Polishing and Glaze (NP/G)	10
	Without Mechanical Polishing and without Glaze (NP/NG)	10

Table 2. Color change of denture base resin groups with different polishing techniques

Color Change	**P/G**	**P/NG**	**NP/G**	**NP/NG**
Water Bath	1,69±0,57Aa	1,27±0,75Aa	2,90±2,05ABa	2,13±0,54Aa
Microwave	1,71±0,86Aa	1,35±0,28Aa	1,76±0,69Aa	2,15±0,44Aa
CAD/CAM	1,99±0,37Aa	1,65±1,44Aa	3,68±3,16Ba	5,33±0,45Bb
Resin 3D	4,32±2,05Ba	3,62±1,01Ba	4,08±1,22Ba	3,74±1,59ABa

Table 3. Surface roughness of denture base resin groups with different polishing techniques

Before TC	P/G	P/NG	NP/G	NP/NG
Water Bath	0,057 ± 0,043Aa	0,028 ± 0,008Aa	0,068 ± 0,026Aa	0,145 ± 0,020Ab
Microwave	0,05 ± 0,026Aa	0,030 ± 0,017Aa	0,086 ± 0,041Ab	0,167 ± 0,026ABc
CAD/CAM	0,039 ± 0,016Aa	0,021 ± 0,006Aa	0,061 ± 0,024Aa	0,167 ± 0,018ABb
Resin 3D	0,040 ± 0,009Aa	0,028 ± 0,006Aa	0,080 ± 0,037Aa	0,205 ± 0,027Bc
After TC	P/G	P/NG	NP/G	NP/NG
Water Bath	0,072 ± 0,059Aab	0,034 ± 0,021Aa	0,135 ± 0,051Abc	0,147 ± 0,022Ac
Microwave	0,057 ± 0,034Aa	0,044 ± 0,25Aa	0,136 ± 0,057Ab	0,176 ± 0,030Ab
CAD/CAM	0,060 ± 0,031Aab	0,045 ± 0,019Aa	0,126 ± 0,070Ab	0,116 ± 0,128Ab
Resin 3D	0,095 ± 0,040Aab	0,050 ± 0,032Aa	0,118 ± 0,078Ab	0,207 ± 0,043Ac

Table 4. Microhardness of denture base resin groups with different polishing techniques

Before TC	P/G	P/NG	NP/G	NP/NG
Water Bath	37,7 ± 5,42Ab	20,7 ± 1,03ABc	32,3 ± 2,09Ab	45,1 ± 3,41Aa
Microwave	37,7 ± 5,27Aa	20,3 ± 1,71ABb	35,7 ± 3,86Aa	42,5± 4,25Aa
CAD/CAM	28,4± 3,63Bbc	23,8 ± 1,94Ac	31,5 ± 2,86Ab	39,8 ± 2,65Aa
Resin 3D	29,2 ± 2,94Bb	17,4 ±1,44Bd	23,2 ± 3,42Bc	40,0 ±2,63Aa
After TC	P/G	P/NG	NP/G	NP/NG
Water Bath	37,9 ±4,91ABa	37,9 ± 2,86Aa	39,1 ± 4,0Aa	41,9 ±2,55Aa
Microwave	40,6 ± 6,11Aa	36,4 ± 1,56Aa	40,2 ±2,54Aa	42,5 ± 5,76Aa
CAD/CAM	37,9 ± 3,47ABa	36,3 ± 1,79Aa	38,5 ± 2,96Aa	41,7 ± 1,35Aa
Resin 3D	32,3 ± 5,17Ba	17,9 ± 1,44Bc	26,1 ± 2,35Bb	34,3 ± 4,34Ba

3 CONCLUSÃO

Podemos concluir que não houve diferença para microdureza entre as demais resinas independentes do tipo de polimento avaliado. Os tipos de polimentos avaliados não influenciaram na microdureza das resinas banho maria, microondas e CAD/CAM. A ausência do polimento mecânico contribuiu para maior alteração de cor e rugosidade. Entretanto, os diferentes tipos de resinas utilizadas para base de prótese total não interferem nos parâmetros de alteração de cor e rugosidade.

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Authors are requested to submit their original manuscript and figures via the online submission and editorial system for *Dental Materials*. Using this online system, authors may submit manuscripts and track their progress through the system to publication. Reviewers can download manuscripts and submit their opinions to the editor. Editors can manage the whole submission/review/revise/publish process. Please register at: https://www.editorialmanager.com/dentma/default.aspx.

Dental Materials now only accepts online submissions.

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Reporting guidance

For research involving or pertaining to humans, animals or eukaryotic cells, investigators should integrate sex and gender-based analyses (SGBA) into their research design according to funder/ sponsor requirements and best practices within a field. Authors should address the sex and/or genderdimensions of their research in their article. In cases where they cannot, they should discuss thisas a limitation to their research's generalizability. Importantly, authors should explicitly state what definitions of sex and/or gender they are applying to enhance the precision, rigor and reproducibility of their research and to avoid ambiguity or conflation of terms and the constructs to which they refer (see Definitions section below). Authors can refer to the Sex and Gender Equity in Research (SAGER) guidelines and the SAGER guidelines checklist. These offer systematic approaches to the useand editorial review of sex and gender information in study design, data analysis, outcome reporting and research interpretation - however, please note there is no single, universally agreed-upon set ofguidelines for defining sex and gender.

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Sex generally refers to a set of biological attributes that are associated with physical and physiological features (e.g., chromosomal genotype, hormonal levels, internal and external anatomy). A binary sexcategorization (male/female) is usually designated at birth ("sex assigned at birth"), most often based solely on the visible external anatomy of a newborn. Gender generally refers to socially constructedroles, behaviors, and identities of women, men and gender-diverse people that occur in a historical and cultural context and may vary across societies and over time. Gender influences how people viewthemselves and each other, how they behave and interact and how power is distributed in society. Sexand gender are often incorrectly portrayed as binary (female/male or woman/man) and unchangingwhereas these constructs actually exist along a spectrum and include additional sex categorizationsand gender identities such as people who are intersex/have differences of sex development (DSD) or identify as non-binary. Moreover, the terms "sex" and "gender" can be ambiguous—thus it is important for authors to define the manner in which they are used. In addition to this definition guidance and the SAGER guidelines, the resources on this page offer further insight around sex and gender in research studies.

Authorship

All authors should have made substantial contributions to all of the following: (1) the conception anddesign of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

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This must be presented in a structured format, covering the following subjects, although actualsubheadings should not be included:

- succinct statements of the issue in question;
- the essence of existing knowledge and understanding pertinent to the issue (reference);

- the aims and objectives of the research being reported relating the research to dentistry, wherenot obvious.

Materials and methods

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- only cite references to published methods.
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- identify names and sources of all commercial products e.g.

"The composite (Silar, 3M Co., St. Paul, MN, USA)..."
"... an Au-Pd alloy (Estheticor Opal, Cendres et Metaux, Switzerland)."

- specify statistical significance test methods.

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- state implications of the results, relate to composition.
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Conclusion (if included)

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[5] Cancer Research UK. Cancer statistics reports for the UK, http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/; 2003 [accessed 13 March 2003].

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