

# Surface and microhardness alterations of denture materials following exposure to gastric juice

Alterações superficiais e microdureza de materiais para prótese dentária após exposição ao suco gástrico

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## ABSTRACT

**Objective:** To analyze the effects of exposure to simulated gastric juice on the mechanical properties and surface characteristics of resins used for partial and complete dentures. **Material and Methods:** Thirty discs of heat-polymerized, 3D-printed, and milled resins were fabricated and polished. Specimens were allocated into two groups according to the immersion medium: artificial saliva or simulated gastric juice. The degree of conversion of C=C bonds (DC) of heat-polymerized and 3D-printed resins was determined by Fourier-transform infrared spectroscopy. Surface characteristics were evaluated by surface roughness (Ra and Rz) and Knoop microhardness at baseline, 6 months and 1 year of exposure. Complementary scanning electron microscopy was performed. Roughness values were analyzed using the Friedman and Durbin-Conover tests, and microhardness by repeated-measures ANOVA and Tukey's test ( $\alpha = 0.05$ ). **Results:** The degree of conversion was 85% for heat-polymerized resins and 65% for 3D-printed resins. At baseline, all materials exhibited relatively smooth surfaces with polishing marks. After exposure, surface morphology remained similar to the original, except for the heat-polymerized resin exposed to the acidic medium. Ra roughness was not affected by the immersion media ( $p = 0.449$ ). However, time and material type significantly influenced microhardness ( $p = 0.002$  and  $p < 0.001$ , respectively). **Conclusion:** Both immersion media reduced the microhardness of all resins. However, the extent of degradation caused by simulated gastric juice and artificial saliva was similar among heat-polymerized, milled, and 3D-printed resins.

## KEYWORDS

CAD-CAM; Complete denture; Gastric juice; Mechanical tests; Printing three-dimensional.

## RESUMO

**Objetivo:** Analisar os efeitos da exposição ao suco gástrico simulado nas propriedades mecânicas e nas características de superfície de resinas utilizadas para próteses parciais e totais. **Material e Métodos:** Trinta discos de resinas termopolimerizadas, impressas em 3D e fresadas foram confeccionados e polidos. Os espécimes foram alocados em dois grupos de acordo com o meio de imersão: saliva artificial ou suco gástrico simulado. O grau de conversão das ligações C=C (DC) das resinas termopolimerizadas e impressas em 3D foi determinado por espectroscopia no infravermelho por transformada de Fourier. As características da superfície foram avaliadas por meio da rugosidade superficial (Ra e Rz) e da microdureza Knoop no início do estudo, após 6 meses e após 1 ano de exposição. Foi realizada microscopia eletrônica de varredura complementar. Os valores de rugosidade foram analisados utilizando os testes de Friedman e Durbin-Conover, e a microdureza por ANOVA de medidas repetidas e teste de Tukey ( $\alpha = 0,05$ ). **Resultados:** O grau de conversão foi de 85% para as resinas termopolimerizadas e de 65% para as resinas impressas em 3D. No baseline, todos os materiais apresentaram superfícies relativamente lisas com marcas de polimento. Após a exposição, a morfologia superficial permaneceu semelhante à original, exceto para a resina termopolimerizada exposta ao meio ácido. A rugosidade Ra não foi afetada pelos meios de imersão ( $p = 0,449$ ). No entanto, o tempo e o tipo de material influenciaram significativamente a microdureza ( $p = 0,002$  e  $p < 0,001$ , respectivamente). **Conclusão:** Ambos os meios de imersão reduziram a microdureza de todas as resinas. Entretanto, a extensão da degradação causada pelo suco gástrico simulado e pela saliva artificial foi semelhante entre as resinas termopolimerizadas, fresadas e impressas em 3D.

## PALAVRAS-CHAVE

CAD-CAM; Prótese total; Suco gástrico; Avaliação das propriedades mecânicas; Impressão tridimensional.

## INTRODUCTION

Edentulism, defined as the complete loss of natural teeth, remains a significant global public health concern, particularly among older adults. According to the World Health Organization, approximately 23% of adults aged 50 years or older are edentulous worldwide, highlighting the substantial burden of this condition in aging populations [1]. Individuals with edentulism frequently present comorbidities such as respiratory, mental, musculoskeletal, metabolic, and cardiovascular disorders. These medical conditions, along with the use of certain medications, have been linked to an increased risk of gastroesophageal reflux disease [2-4].

During regurgitation, gastric juice may reach the oral cavity, compromising dental tissues and restorative materials [2,5-8]. The contact of gastric juice with dental tissues can lead to erosion, and the subsequent demineralization and dentin exposure often require both direct and indirect restorations [9]. Regarding dental materials such as resin composites, surface degradation, increased roughness, and higher bacterial adhesion have been reported [10,11]. Although studies indicate that patients with gastrointestinal disorders exhibit a significantly higher rate of denture failure compared to individuals without these conditions [1-3], longitudinal data documenting the progression of these failures over time remain scarce.

The durability and surface characteristics of prosthetic materials may be compromised by a range of oral challenges, including staining [12] and microbial colonization [13,14]. In patients with gastrointestinal disorders, repeated exposure to acidic gastric content represents an additional risk factor that may accelerate material degradation. Currently, dentures can be fabricated using various methods, including conventional techniques with heat-polymerized acrylic resin, as well as digital workflows involving milling or 3D printing [15-17]. Despite being relatively recent, the latter two techniques have demonstrated clinical success [16,18], offering benefits such as fewer required appointments, improved retention, reduced operator dependency, and the ability to preserve digital records [19]. As a recent technique, there remains a lack of studies evaluating the effects of gastric juice on these materials, which are commonly used for the fabrication of denture teeth and bases.

Denture base materials are continuously exposed to the oral environment, where factors such as moisture, temperature fluctuations, and chemical challenges may contribute to their aging over time. Prolonged exposure to aqueous and acidic conditions can promote water sorption and hydrolytic degradation of the polymeric matrix, potentially affecting the structural stability and surface characteristics of these materials. These aging-related processes may compromise the long-term performance and clinical longevity of dentures, highlighting the importance of evaluating material behavior over extended periods [17-19].

Therefore, this study aimed to analyze the effects of simulated gastric juice on the mechanical properties and surface characteristics of materials used in the fabrication of denture bases and artificial teeth, with a focus on 3D-printed resins. It was hypothesized that exposure to gastric juice would significantly decrease the mechanical properties and increase surface roughness of these materials over time.

## MATERIAL AND METHODS

### Study design

This *in vitro* study evaluated three factors: manufacturing methods (in three levels: 3D-printed, milled, or heat-activated resin), immersion media (in two levels: simulated gastric juice or artificial saliva), and time (in three levels: baseline, 6 months, or 1 year). Evaluations of microhardness, roughness, and surface topography were carried out. The same specimens were evaluated over time for roughness and microhardness (repeated measures approach). Additionally, Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy analyses were performed. The sample size was determined based on a pilot study. The calculations were performed in a statistical website [20] using roughness (Ra) as the primary response variable. The mean difference and standard deviations considered were 0.2 and 0.1, respectively, with a desired power of 0.8, and  $\alpha = 0.05$ , which resulted in a minimum of six specimens per group. The materials used in this study are described in Table I.

### Specimens' preparation

Heat-polymerized acrylic resin (Lucitone, Dentsply Sirona, New York, USA) and 3D-printed

**Table I** - Materials, manufacturers, composition, and lot number used in this study

Comercial brand	Manufacturer	Composition	Lot
Lucitone 550 Classe I	Dentsply Sirona, New York, USA	Powder: (methyl-n-butyl) methacrylate copolymer, benzoyl peroxide, and mineral pigments. Liquid: methyl methacrylate, ethylene glycol methacrylate, and hydroquinone.	794173F
V-Print Dentbase	VOCO, Cuxhaven, Germany	Aliphatic urethane dimethacrylate (50–100%), Ethoxylated bisphenol A dimethacrylate (25–50%), Triethylene glycol dimethacrylate (5–10%), Diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide (<2.5%).	2407792
Ceditec-DT	VOCO, Cuxhaven, Germany	27% by weight of inorganic filler substances in a polymeric matrix.	2425085

resin (V-Print DentBase, VOCO, Cuxhaven, Germany) are indicated for denture bases, whereas the milled resin (CediTEC DT, VOCO, Cuxhaven, Germany) is indicated for the fabrication of artificial teeth. A total of thirty discs-shaped specimens (12mm in diameter and 2mm in thickness) were fabricated from the evaluated materials.

The Heat-activated acrylic resin samples were obtained by embedding printed model discs, made exclusively for this purpose. The printed specimens were molded with an impression material (Zetalabor®, Zhermack, Badia Polesine, Italy) in a dental flask for the fabrication of acrylic resin discs (Lucitone, Dentsply Sirona, New York, USA). Excess acrylic resin was removed during the muffle pressing process to prevent porosity from forming during this stage. The muffle furnace was then submerged in a water bath polymerization unit (polymerizer) until the material had polymerized completely. The polymerization cycle used for the specimens followed the manufacturer's recommendations for the Lucitone 550 acrylic resin (water bath: 90 minutes at 73 °C + 30 minutes at 100 °C).

For the 3D-printed resin specimens, the samples were designed using Rhinoceros 7.0 SR8 software (McNeel, North America, Seattle, USA). The models were exported as stereolithography (STL) files and imported into the printer slicing software (Composer 2.0), where the printing parameters were defined, including cylindrical support structures, a layer exposure time of 5.34 s, printing angle of 0°, and a layer thickness of 0.050 mm. The specimens were printed using a V-Print Dentbase resin (VOCO, Cuxhaven, Germany) with an ASIGA® MAX UV 385 printer (Asiga, Sydney, Australia), which operates using Digital Light Processing (DLP) technology. The printing process was conducted at a controlled temperature of 30 °C, and the specimens were

positioned at a build orientation of 0°, parallel to the build platform, in order to standardize specimen fabrication and minimize the need for support structures. After printing, the specimens were cleaned in 96% isopropyl alcohol for 15 minutes in an ultrasonic bath to remove uncured resin residues, according to the manufacturer's recommendations for this type of resin. The samples were then dried with absorbent paper and subjected to a post-polymerization process in an Otofash® G171 photopolymerization unit (VOCO, Cuxhaven, Germany) using 2,000 flash pulses on each side of the specimen, totaling 4 minutes of post-curing.

The milled resin discs were made from a circular specimen cutter machine (MicroMil, Washington, USA), where cylinders were obtained (12 mm in diameter and 50 mm in length). The cylinders were then transferred to a precision cutter (Isomet 1000, Buehler, Lake Bluff, USA), where they were sectioned into 2-mm thick discs.

After manufacturing, all specimens were polished with abrasive papers of #400, #600, #1200, and #2000 grit in a polisher (Ecomet 250, Buehler, Lake Bluff, USA) under water cooling until reaching an average initial roughness (Ra) of 0.05 µm. Next, the samples were polished with a dry felt disk attached to a lathe (Nevoni, Barueri, São Paulo, Brazil) and an ultrafine diamond paste (Diamond Excel, FGM, Brazil)[CR1.1]. Finally, the specimens were cleaned in an ultrasonic bath with ethanol and dried in an oven at 37 °C for 48 minutes to allow evaporation of residual solvent and moisture prior to testing. The conditioning temperature was selected to approximate intraoral conditions, following recommendations for denture base polymers described in ISO 20795-1.

The specimens were divided into two experimental groups: exposed to artificial saliva or simulated gastric juice (0.113% hydrochloric acid in deionized water with pH of 1.2) [5].

The artificial saliva was prepared in a compounding laboratory and consisted of potassium chloride, sodium chloride, magnesium chloride, calcium chloride, carboxymethylcellulose, biodistilled glycerin, sorbitol, methylparaben (nipagin), and deionized water (H<sub>2</sub>O). The measured pH of saliva was 6.27, while that of simulated gastric juice was 1.99. For pH measurement, a DM-20 pH meter (Digimed, São Paulo, Brazil) was used, calibrated with standard solutions (Storage Solution for pH and electrodes, Hanna Instruments, Barueri, São Paulo, Brazil, Batch 7128) at pH 4.0 and 6.5. After calibration, three readings were taken for each of the evaluated liquids. The specimens were individually immersed in 3 mL of each liquid in a 24 well-plate in an incubator at 37°C. The time points for evaluations were baseline (T0), 4 hours and 36 minutes (T1) and 9 hours and 12 minutes (T2), corresponding to 6 months and 1 year of clinical use, respectively [5]. At each exposure time, the samples were removed from the immersion media for being subjected to the analyses and were stored in distilled water during the analyses period.

### Degree of C=C conversion

The heat-activated acrylic resin and the 3D-printed resin were had their degree of C=C conversion (DC) determined using Fourier-transform infrared (FTIR) spectroscopy (n=5). Spectral measurements of the specimens were first taken using a drop of the printed resin in its unpolymerized form, and the thermally activated heat-polymerized acrylic resin was evaluated immediately following the mixing process. DC was quantified using the resolution of 4 cm<sup>-1</sup> and 32 scans, using the absorbance method. Both resins were analyzed based on the peak at 1,637 cm<sup>-1</sup>, which are associated with aliphatic C=C bonds, corresponding to the methacrylic monomers (UDMA and TEGDMA). In the case of the studied impression resin, the composition includes the monomers urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA), both containing highly reactive methacrylic groups, which are mainly responsible for the formation of the three-dimensional polymer network after light activation. The Equation 1 was used to calculate the degree of conversion (DC%) [21]:

$$DC(\%) = 100 \times \frac{h_0 - h_t}{h_0} \quad (1)$$

where h<sub>0</sub> and h<sub>t</sub> represent, respectively, the height of the absorption band corresponding to the reactive methacrylate group in relation to the baseline (or reference band), before the start of polymerization and after the curing time t. The reduction in this height over time reflects the conversion of the C=C groups of the methacrylic monomers (such as UDMA and TEGDMA) into single bonds during the formation of the polymer network.

### Roughness analysis

Three measurements on each specimen (n = 16) were performed with a contact roughness tester (Surftest SJ 400, Mitutoyo, Tokyo, Japão). Three measurements were performed on the x-axis, and three were taken on the y-axis for each sample, using a cut-off of 0.80 mm, resolution 0.0001 μm (range of 8 μm), speed of 0.5 mm/s and total length of 4 mm (ISO 4287/1997). The parameters evaluated were the average roughness (Ra, μm) and the average of the five highest peaks and five deepest valleys (Rz, μm). The average of these three readings was used for the statistical analyses.

### Knoop microhardness analysis

The Knoop microhardness was assessed using a microhardness tester (Shimadzu HMV-G21DT, Shimadzu, Kyoto, Japan). The polished surface of the discs (n=6) was subject to three indentations using a static load of 100 g for 30 seconds. The Knoop Hardness (KH) was calculated by the equation [2].

$$KHN = \frac{P}{A} = \frac{P}{C_p L^2} \quad (2)$$

where P = applied load (kgf), A = surface area of the impression (mm<sup>2</sup>), L = impression length along the longest axis (mm), C<sub>p</sub> = correction factor related to the shape of the indenter (0.070279).

### Scanning electron microscopy

One representative specimen for each condition (n = 3) (T0, T1, and T2 exposed to artificial saliva and simulated gastric juice) were ultrasonically cleaned for 5 minutes, air dried, and gold-sputtered for 160 seconds at 40 mA (Denton Vacuum Desk II). Then, they were analyzed using a scanning electron microscope (MEV, Inspect S50, FEI Company, República Tcheca) at 15 kV with a magnification of 3000× to evaluate the surface characteristics.

## Statistical analysis

Statistical analysis was performed using the Jamovi software program (version 6.0, Sydney, Australia). Data were tested for homoscedasticity (Levene's test) and normality (Shapiro-Wilk test). Ra and Rz values were evaluated using the Friedman test, with multiple comparisons using Durbin-Conover. Microhardness was evaluated using Repeated Measures ANOVA (time \* material interaction), and multiple comparisons were evaluated using Tukey's test.

## RESULTS

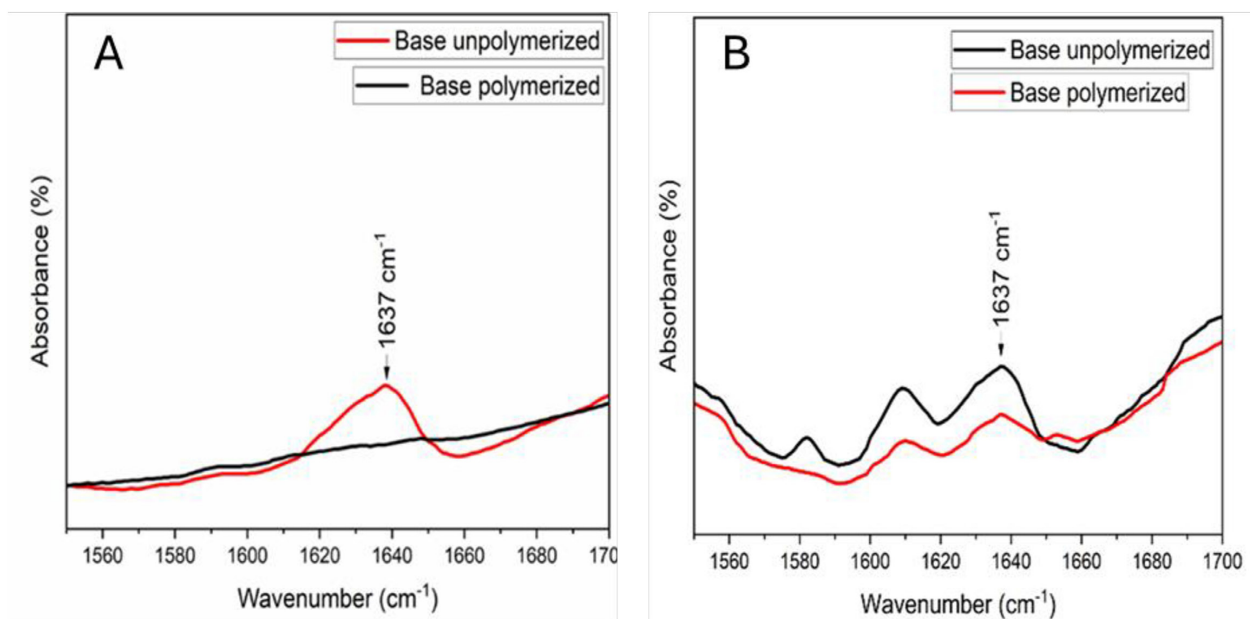
### Degree of C=C conversion

The FT-IR spectra (Figure 1a-1b) exhibited peaks corresponding to polymerized and

unpolymerized heat-polymerized acrylic resin and 3D-printed resin. The degree of C=C conversion of the heat-polymerized acrylic resin revealed a conversion rate of 82% and 3D-printed resin base revealed a conversion rate of 65%.

### Roughness

Table II describes the roughness results obtained for each experimental group. In this study, Ra was not affected by the immersion media ( $p=0.386$ ), time ( $p=0.056$ ), material ( $p=0.603$ ), liquid\*time ( $p=0.917$ ), time\*material ( $p=0.536$ ), liquid\*material ( $p=0.685$ ), or time\*liquid\*material factors ( $p=0.449$ ). On the other hand, Rz was affected by time ( $p=0.009$ ) and the interaction between time and material ( $p=0.021$ ), which revealed that the heat-polymerized material showed lower values after the 1-year immersion compared to the baseline.



**Figure 1** - Fourier Transform Infrared Spectroscopy spectrum displaying the C=C stretching vibrations ( $1637\text{ cm}^{-1}$ ) of non-converted heat-polymerized acrylic resin and 3D printed resin. A: graph related to the milled resin. B: graph related to the printed resin.

**Table II** - Means and standard deviation of roughness (Ra and Rz,  $\mu\text{m}$ ). Obtained from each experimental group

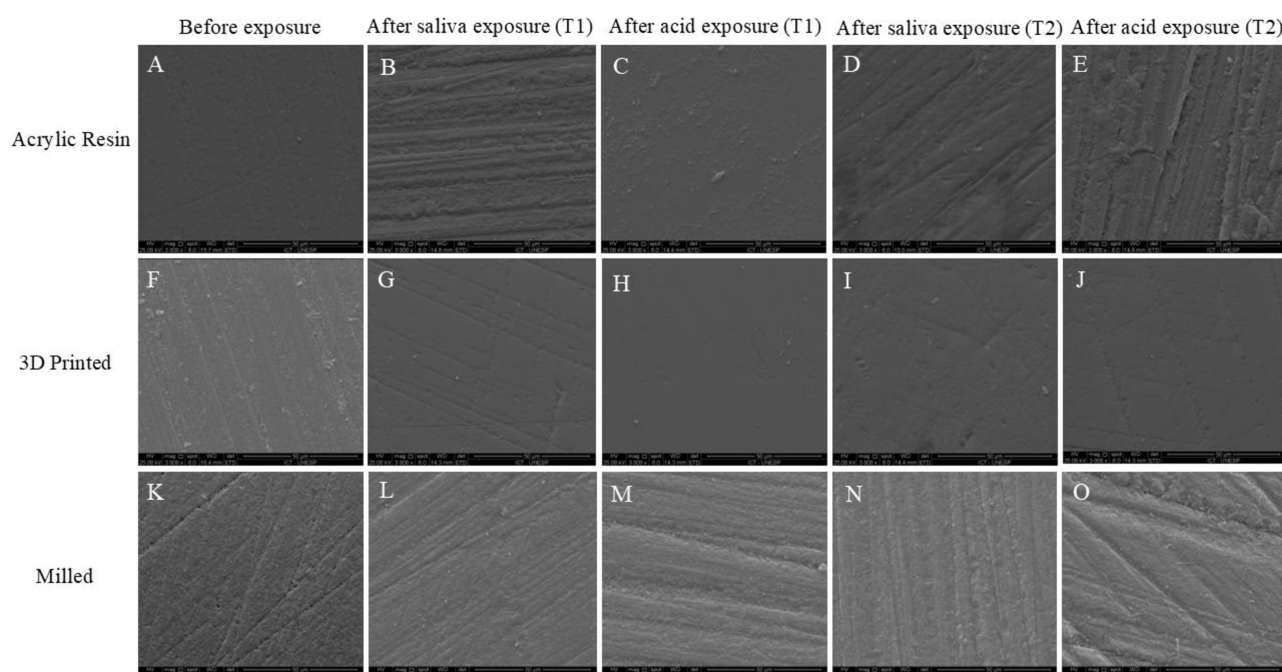
		Ra ( $\mu\text{m}$ )			Rz ( $\mu\text{m}$ )		
		T0	T1	T2	T0	T1	T2
Simulated gastric juice	Heat-polymerized	0.11 (0.07)	0.06 (0.03)	0.05 (0.01)	1.15 (0.55)*	0.39 (0.22)	0.38 (0.19)*
	3D-Printed	0.08 (0.03)	0.11 (0.04)	0.06 (0.01)	0.75 (0.55)	0.64 (0.25)	0.73 (0.34)
	Milled	0.08 (0.03)	0.12 (0.04)	0.09 (0.05)	0.57 (0.23)	0.77 (0.25)	0.46 (0.10)
Artificial saliva	Heat-polymerized	0.1 (0.05)	0.09 (0.03)	0.05 (0.01)	2.18 (3.18)*	0.64 (0.24)	0.40 (0.13)*
	3D-Printed	0.06 (0.02)	0.09 (0.03)	0.12 (0.01)	1.02 (1.54)	0.66 (0.28)	0.61 (0.46)
	Milled	0.05 (0.01)	0.1 (0.06)	0.07 (0.04)	0.40 (0.10)	0.21 (0.17)	0.50 (0.21)

\*Indicates statistical difference for the interaction between time and material ( $p<0.05$ ). No statistical differences were observed for Ra.

**Table III** - Means and standard deviation of microhardness (KHN)

		Microhardness (KHN)		
		T0	T1	T2
Simulated gastric juice	Acrylic Resin	18.3 (1.18) <sup>Aa</sup>	17.2 (2.83) <sup>ABa</sup>	9.22 (0.19) <sup>Ba</sup>
	3D Printed	19.4 (0.49) <sup>Aa</sup>	18.9 (0.35) <sup>ABa</sup>	15.5 (2.57) <sup>Ba</sup>
	Milled	23.7 (5.80) <sup>Ab</sup>	26.9 (0.54) <sup>ABb</sup>	23.0 (1.70) <sup>Bb</sup>
Artificial saliva	Acrylic Resin	17.1 (1.44) <sup>Aa</sup>	18.8 (1.37) <sup>ABa</sup>	16.9 (1.27) <sup>Ba</sup>
	3D Printed	17.7 (2.66) <sup>Aa</sup>	17.4 (1.48) <sup>ABa</sup>	14.6 (3.80) <sup>Ba</sup>
	Milled	27.7 (1.32) <sup>Ab</sup>	31.7 (4.03) <sup>ABb</sup>	25.1 (2.24) <sup>Bb</sup>

Uppercase letters indicate a statistical difference for time. Lowercase letters indicate a statistical difference for material.



**Figure 2** - Scanning Electron Microscopy of the surfaces of Acrylic Resin, 3D printed and milled material before and after exposure, under 3000 x magnification. All specimens presented polishing marks, with no clear topographic differences between groups.

## Microhardness

Table III describes the results of microhardness. Time ( $p=0.002$ ) and material ( $p<0.001$ ) significantly influenced microhardness, showing significant statistical differences related to milled resin at different exposure times, when compared to other materials. All tested material had their microhardness values significantly decreased after T2 when compared to T0. However, milled resin achieved the highest results in all study times.

## Scanning electron microscopy

Scanning electron microscopy analysis did not reveal evident surface topographical changes after exposure to artificial saliva or simulated gastric juice (Figure 2). Polishing marks were observed on the surfaces of all specimens.

## Discussion

Gastric juice did not affect the mechanical properties of the materials over time compared to artificial saliva; however, the milled material presented a superior mechanical behavior compared to 3D-printed and heat-polymerized resins. Based on these results, the tested hypothesis was rejected.

When different materials indicated for the fabrication of removable prostheses come into contact with an acidic substance ( $pH=1.99$ ) and artificial saliva, a reduction in microhardness was observed over time for the 3D-printed and heat-polymerized resins. Previous studies have reported that polymeric materials subjected to simulated gastric juice do not exhibit significant changes in microhardness or mass loss, although surface roughness may be reduced or maintained [5].

In contrast, the findings of this study suggest that both acidic and neutral solutions can negatively affect all the resins studied herein over time, emphasizing the need for further investigations into their long-term stability in the oral environment. Both acidic and neutral solutions may negatively affect resin-based materials over time due to water sorption and hydrolytic degradation within the polymer matrix. The diffusion of water molecules into the polymer network may cause plasticization to increase chain mobility and weaken intermolecular interactions. Additionally, aqueous environments may promote hydrolysis of ester bonds and the leaching of residual monomers, which may gradually compromise the mechanical properties of the material [22,23].

When comparing the composition and technical processing of heat-polymerized, 3D-printed, and milled resins, notable differences become apparent. Milled polymethyl methacrylate (PMMA) has been reported to exhibit superior wear resistance and color stability compared to 3D-printed and conventionally processed PMMA [24]. This can be attributed to the fact that milled materials are produced industrially under controlled conditions. On the other hand, both acrylic and 3D-printed resins are typically fabricated in dental laboratories, where factors such as pre-processing, processing, and post-processing steps may significantly influence their final properties [25]. These factors include the degree of C=C conversion, which in our study was 65% for the 3D-printed resin, while for heat-polymerized acrylic resin a conversion rate of 82% was revealed. The degree of conversion of the milled material could not be determined; however, it is possibly higher than that of the heat-polymerized and 3D-printed materials due to controlled industrial manufacturing.

Although a reduction in microhardness was observed, signs of degradation were not visible in the scanning electron microscopy images. Hipólito and collaborators pointed out that this phenomenon can be explained by the inherent water sorption of resin-based materials, a process that is intensified in acidic environments [18]. Moreover, when a resin material undergoes the process of liquid sorption, its polymer matrix expands due to the separation of its polymer chains. This allows the acid corrosion to intensify over time, in addition to the natural degradation that dental materials experience in the oral environment [18]. Polymer expansion is caused

by water sorption, which is determined by the polarity of PMMA molecules and the spaces between polymer chains created by residual monomers, as well as surface porosities in the resin that may also contribute to increased water sorption. Furthermore, the reduction in Rz observed in the heat-polymerized material might be associated with this polymer expansion occurring in PMMA [19,22].

The average roughness values reported from all tested materials fall within clinically acceptable limits ( $0.2\ \mu\text{m}$ ) [26] and all Ra values were below  $0.5\ \mu\text{m}$ , indicating that surface texture is unlikely to be perceptible or cause discomfort to patients. These favorable Ra values may contribute to reduced bacterial adhesion and biofilm formation [27,28], which is beneficial for oral health, particularly in immunocompromised individuals or those with poor oral hygiene [29]. However, one should note that this study simulated a maximum usage period of one year. Since removable prostheses are often used for longer durations, it remains uncertain whether prolonged exposure to gastric juice, combined with brushing, would degrade the materials and compromise their longevity.

This study also aimed to assess whether new materials developed for removable prostheses, such as printed and milled ones, are affected by gastric juice and artificial saliva. These materials behaved similarly and showed some degradation over time in moisture. Over the past few years, researchers have been studying methods to better process 3D-printed materials and obtain greater mechanical and optical properties [21,27,30,31]. For these materials, it is also suggested to test new protocols, such as combining mechanical and chemical oral hygiene methods, to verify their stability in relation to roughness and the impact of these attributes on the microhardness of the materials used. Additionally, new research should analyze fatigue resistance, which is also critical for prosthesis longevity.

This study provides novel insights into the effects of gastric juice on materials used for removable prostheses. Limitations of this study include the lack of thermal aging evaluation, which could have influenced outcomes related to roughness and microhardness. Future studies should incorporate thermocycling, mechanical loading, or brushing to better simulate intraoral conditions or perform in situ aging tests.

Additionally, as gastric fluid composition varies among individuals, only one concentration of gastric juice can underestimate its effects on materials. Nonetheless, our findings suggest that gastric juice itself does not compromise the surface characteristics of heat-polymerized, milled, or 3D-printed resins for removable prostheses within one year of exposure. Further research is warranted to confirm these results.

## CONCLUSIONS

Both gastric juice and saliva led to a decrease in the hardness of heat-polymerized, milled, and 3D-printed resins over time. However, the surface characteristics of these materials were not compromised by either immersion media throughout the experimental period.

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## Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Author's Contributions

CSR, RMM: Conceptualization. LTSP, NMFG, CMLS, PVSS: Formal Analysis. LTSP, NMFG, CMLS, PVSS, AJTN, CSR, RMM: Investigation. AJTN, CSR, RMM: Methodology. CSR, RMM: Project Administration. ALSB: Resources. CMLS, PVSS: Software. CSR, RMM: Supervision. ALSB, CSR, RMM: Validation. LTSP, NMFG, AJTN: Writing – Original Draft Preparation. LTSP, NMFG, CSR, RMM: Writing – Review & Editing.

## Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

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## Regulatory Statement

Not applicable.

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