**UNIVERSIDADE DE UBERABA**

**MESTRADO ACADÊMICO EM ODONTOLOGIA**

**LAIANNE VIEIRA MENDES**

# REMOÇÃO DE ADESIVOS PARA PRÓTESE DENTÁRIA DA SUPERFÍCIE DE RESINAS À BASE DE POLIMETILMETACRILATO E IMPRESSA EM 3D

UBERABA-MG

2025

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Dissertação apresentada ao Programa de Pós-Graduação em Odontologia - Mestrado Acadêmico da Universidade de Uberaba, como requisito para obtenção do título de Mestre em Odontologia, na Área de Concentração em Clínica Odontológica Integrada.

Orientadora: Profa. Dra. Denise Tornavoi de Castro.

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Dissertação apresentada como parte dos requisitos para obtenção do título de Mestre em Odontologia do Programa de Pós-Graduação em Odontologia - Mestrado da Universidade de Uberaba.

Área de concentração: Clínica Odontológica Integrada

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BANCA EXAMINADORA:

Profª. Drª. Denise Tornavoi de Castro
Orientadora
Universidade de Uberaba

Prof. Dr. Cesar Penazzo Lepri
Universidade de Uberaba

Profª. Drª. Ana Beatriz Vilela Teixeira
Faculdade de Odontologia da Universidade do Estado do Rio de Janeiro

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# RESUMO

Os adesivos protéticos são auxiliares na retenção e na estabilidade das próteses dentárias removíveis. Entretanto, a remoção incompleta desses materiais durante a higienização pode favorecer o acúmulo de biofilme, prejudicar a estabilidade da prótese e alterar a dimensão vertical de oclusão do paciente. Esse estudo avaliou a rugosidade superficial e a molhabilidade do polimetilmetacrilato (PMMA) e da resina impressa e a eficácia de métodos para a remoção de adesivos da superfície desses materiais. Foram confeccionadas 60 amostras de cada material, as quais foram polidas em apenas um dos lados. A rugosidade superficial foi avaliada em um rugosímetro portátil e a molhabilidade em um goniômetro pelo método da gota séssil. As amostras foram hidratadas por 24 horas, secas e pesadas (P1). Receberam 0,10 gramas dos adesivos Ultra Corega Creme e Fixodent e foram armazenadas em estufa por 1 hora. A seguir, foram divididas em três grupos de acordo com o método de higienização: mecânico - escovação; químico - imersão em pastilha efervescente (Corega Tabs) e combinado - imersão em pastilha efervescente Corega Tabs + escovação. Após a higienização, as amostras foram secas, inseridas no forno por 45 minutos, pesadas novamente (P2) e coradas para a quantificação do adesivo remanescente no software ImageJ. Os dados foram submetidos à ANOVA e pós teste de Bonferroni ($\alpha=5\%$). O PMMA apresentou maior rugosidade ($p<0,001$) e maior hidrofobicidade ($p=0,009$). O polimento foi capaz de promover rugosidade semelhante aos materiais ($p=0,820$). Ao considerar a diferença de peso das amostras (P2 – P1) nota-se que o método químico promoveu maior quantidade de adesivo remanescente ($p<0,001$). Houve menor quantidade do Corega na superfície da resina impressa e do Fixodent no PMMA. A resina impressa apresentou maior área recoberta por adesivo do que o PMMA ($p<0,001$). O método combinado promoveu menor área recoberta pelo adesivo ($p<0,05$). Observa-se maior área da resina impressa recoberta pelo Fixodent do que do PMMA ao utilizar os métodos mecânico e combinado ($p<0,05$). Conclui-se que a superfície do PMMA é mais rugosa e hidrofóbica do que da resina impressa, e o polimento promove rugosidade semelhante. Os métodos mecânico e combinado foram mais efetivos na remoção do adesivo. Os adesivos se comportaram de forma diferente nos materiais uma vez que o Corega foi mais facilmente removido da superfície da resina impressa e o Fixodent do PMMA.

**Palavras-chave:** adesivo protético; higienização; impressão 3D; teste de remoção; polimetilmetracrilato.

## ABSTRACT

Denture adhesives are aids to retention and stability of removable dentures. However, incomplete removal of these materials during hygiene can promote biofilm accumulation, compromise prosthesis stability and alter the patient's vertical occlusal dimension. This study evaluated the surface roughness and wettability of polymethylmethacrylate (PMMA) and printed resin, and the effectiveness of methods for removing adhesives from the surface of these materials. Sixty samples of each material were made and polished on one side only. Surface roughness was measured using a portable roughness meter and wettability was measured using a goniometer by the sessile drop method. The samples were hydrated for 24 hours, dried and weighed (W1). They received 0.10 grams of Ultra Corega Cream and Fixodent adhesives and were stored in an oven for 1 hour. They were then divided into three groups according to the hygiene method: mechanical - brushing; chemical - immersion in an effervescent tablet (Corega Tabs) and combined - immersion in an effervescent tablet Corega Tabs + brushing. After hygienization, the samples were dried, placed in an oven for 45 minutes, reweighed (W2) and stained to quantify residual adhesive using ImageJ software. The data were subjected to ANOVA and Bonferroni post-test ($\alpha=5\%$). PMMA showed greater roughness ($p<0.001$) and greater hydrophobicity ($p=0.009$). Polishing was able to promote similar roughness to the materials ($p=0.820$). When looking at the difference in weight of the samples (W2 - W1), it can be seen that the chemical method promoted a greater amount of residual adhesive ($p<0.001$). There was less Corega on the surface of the printed resin and Fixodent on the PMMA. The printed resin had a larger area covered by adhesive than the PMMA ($p<0.001$). The combined method resulted in a smaller area covered by adhesive ($p<0.05$). There was a greater area of printed resin covered by Fixodent than PMMA when using the mechanical and combined methods ($p<0.05$). It can be concluded that the PMMA surface is rougher and more hydrophobic than the printed resin and that polishing promotes similar roughness. The mechanical and combined methods were more effective in removing the adhesive. The adhesives behaved differently on the materials, with Corega being easier to remove from the printed resin surface and Fixodent being easier to remove from PMMA.

**Keywords:** denture adhesive; cleaning; 3D printing; removal test; polymethyl methacrylate.

**Sumário**

# 1 INTRODUÇÃO

As próteses totais removíveis convencionais ainda representam a principal opção de tratamento para pacientes edêntulos (MOYNIHAN; VARGHESE, 2022). Na maioria dos casos, os materiais utilizados para a fabricação são as resinas acrílicas a base de polimetilmetacrilato (PMMA) termopolimerizáveis devido às suas propriedades físico-mecânicas (POLYCHRONAKIS *et al*., 2021). Entretanto, desvantagens associadas aos erros envolvidos no processo de confecção, longo tempo clínico, contração de polimerização, porosidade e alto acúmulo de biofilme são relatadas (TOTU *et al*., 2017; HERPEL *et al*., 2021; VILELA TEIXEIRA e DOS REIS, 2023).

Aperfeiçoamentos recentes em ciência e tecnologia forneceram métodos digitais para a produção de base de próteses totais, incluindo a impressão tridimensional (3D) (ALP, MURAT e YILMAZ, 2018; PRPIĆ *et al*., 2020). Essa técnica tem prosperado na odontologia com aplicações em guias cirúrgicos, coroas provisórias, bases de próteses e implantes (PEREA-LOWERY *et al*., 2021). A literatura relata um alto potencial da impressão 3D para modernizar e agilizar a fabricação de próteses totais (ANADIOTI *et al*., 2020).

O sucesso de uma prótese total convencional depende de vários fatores, e não apenas da experiência prévia do profissional que está confeccionando. Fatores como a experiência anterior do paciente com o uso de próteses, o tipo de rebordo e os aspectos psicológicos podem influenciar no resultado final (OWEIS *et al*., 2022). Com o envelhecimento, muitas vezes é difícil manter as próteses confortavelmente na boca devido a fatores sistêmicos e orais, como múltiplas doenças sistêmicas, distúrbios do movimento oral, xerostomia causada pelos efeitos colaterais dos medicamentos, reabsorção do rebordo e alterações mandibulares desencadeadas (BO *et al.*, 2020; NOMURA *et al.*, 2020).

Nos últimos anos, o *American College of Prosthodontists* e a *American Dental Association* expressaram consenso sobre o uso dos adesivos para próteses. Por muito tempo cirurgiões-dentistas evitaram a indicação desses materiais aos seus pacientes, correlacionando sua utilização a falhas técnicas e ao aparecimento de lesões como hiperplasia dos tecidos moles e reabsorção do rebordo alveolar (ELLIS; PELEKIS; THOMASON, 2007; EMAMI *et al.*, 2009; FELTON *et al.*, 2011). Os dentistas naturalmente se esforçam para obter a retenção ideal ao confeccionar uma prótese total, o que não requer necessariamente o uso de um adesivo. No entanto, muitas vezes mesmo profissionais experientes não conseguem satisfazer as expectativas dos pacientes em termos de retenção e estabilidade devido a limitações inerentes ao caso clínico , assim, muitos pacientes usam adesivos protéticos (OWEIS *et al.,* 2022; KOEHLER *et al*., 2024).

Diante desse cenário, os adesivos protéticos são reconhecidos como agentes auxiliares na retenção e na estabilidade das próteses aumentando o desempenho mastigatório e melhorando a qualidade de vida dos portadores de próteses totais (NOMURA *et al.,* 2019; FLORÊNCIO COSTA *et al.,* 2020; ITO *et al.,* 2021). Isso se aplica tanto a próteses bem ajustadas quanto mal ajustadas. No entanto, uma prótese mal ajustada pode promover traumas nos tecidos moles e atrofia acelerada do rebordo. Assim, os adesivos protéticos por si só não podem substituir o papel do dentista (KOEHLER *et al*., 2024).

Em relação a forma comercial, os adesivos protéticos são classificados como pó, creme ou fita e possuem na composição "ingredientes ativos" como goma, carboximetilcelulose de sódio e polímeros sintéticos (por exemplo, óxido de polietileno, acrilamidas e polivinil acético) (POLYCHRONAKIS *et al*., 2021; COSTA *et al*., 2022). Além disso, "ingredientes inativos" como vaselina e óleo mineral atuam como aglutinantes nesses produtos (HAN *et al*., 2014).

Na cavidade bucal, os adesivos tornam-se viscosos devido à absorção de saliva antes de se espalharem entre o rebordo alveolar e a superfície da prótese (COSTA *et al*., 2021). Esse fenômeno é responsável por sua capacidade adesiva; no entanto, as diretrizes do *American College of Prosthodontists* sobre adesivos protéticos também mencionaram seus problemas em relação à limpeza (FELTON *et al*., 2011). Esse fato é importante porque resíduos de adesivos, a presença de uma matriz extracelular ou detritos celulares podem proporcionar maior acúmulo de micro-organismos patogênicos, como a *Candida albicans*, causando estomatite protética (MCREYNOLDS *et al*., 2023; ALVIM *et al*., 2024) e aumentando o risco de pneumonia por aspiração em idosos (IMAI *et al*., 2021). Além disso, resíduos de adesivos podem prejudicar a estabilidade da prótese, pois cada nova camada de adesivo sobre remanescentes de um antigo, aumenta a dimensão vertical de oclusão (BENSON; ROTHMAN E SIMS, 1972). Assim, as principais estratégias para evitar esses problemas devem se concentrar na educação em higiene, principalmente no que se refere aos métodos mais eficazes, já que a limpeza pode ser realizada mecanicamente, quimicamente ou por uma combinação dos dois métodos (COSTA *et al*., 2022).

Poucos estudos examinaram a remoção de adesivos protéticos, e utilizaram as seguintes metodologias de investigação: questionários clínicos, avaliação *in vitro* e estudo clínico (KULAK, OZCAN e ARIKAN, 2005; NUNES *et al*., 2016; AXE *et al*., 2016; HARADA-HADA *et al*., 2016). Os questionários clínicos são um método de avaliação subjetivo, pois dependem da capacidade do paciente em identificar corretamente o adesivo remanescente após a técnica de remoção (AXE *et al*., 2016). Harada-Hada *et al*..2016 avaliaram a eficácia da limpeza de próteses em um estudo *in vitro* comparando fotografias pré e pós-limpeza sem usar nenhum tipo de medição eletrônica/analítica. No entanto, sua classificação foi baseada apenas na inspeção visual. Polychronakis *et al*., 2021 avaliou a facilidade de remoção de adesivos protéticos pelo peso e relatou a eficiência e precisão desta metodologia para estimar a remoção desses materiais das bases protéticas, sendo capaz de indicar pequenas diferenças entre os materiais adesivos.

Por fim, uma vez que nenhum estudo relatou o uso de adesivos em materiais de base de próteses impressos em 3D, questiona-se se há diferença na facilidade de remoção do adesivo nessas superfícies em comparação com superfícies de PMMA. Portanto, o objetivo desse estudo foi avaliar as características de superfície do PMMA e de uma resina impressa em 3D e a eficácia de três métodos de higiene para a remoção de dois adesivos aplicados sobre esses materiais. A hipótese nula é de que não há diferença na rugosidade e na molhabilidade das resinas nem mesmo influência do método de higiene e tipo de adesivo protético, na facilidade de remoção.

# 2 OBJETIVOS

## 2.1 Objetivo geral

O objetivo deste trabalho foi, por meio de metodologia *in vitro*, avaliar as características de superfície de dois materiais utilizados na confecção de próteses totais removíveis e a eficácia de métodos de higiene para a remoção de adesivos protéticos.

## 2.2 Objetivos específicos

- Avaliar a influência da rugosidade do material de base da prótese (PMMA e resina impressa em 3D) na resistência da remoção do adesivo, por meio da análise da rugosidade superficial.
- Avaliar a influência da molhabilidade do material de base da prótese (PMMA e resina impressa em 3D) na resistência da remoção do adesivo, por meio do método da gota séssil.
- Avaliar a eficácia dos métodos de higiene na remoção dos adesivos da superfície do PMMA e da resina impressa em 3D por meio das diferenças gerais no peso entre as amostras.
- Avaliar a eficácia dos métodos de higiene na remoção dos adesivos da superfície do PMMA e da resina impressa em 3D por meio do cálculo da área da amostra coberta com adesivo.
- Registrar possíveis diferenças na absorção de água e subsequentes alterações volumétricas dos adesivos testados.

# 3 CAPÍTULO 1

**Effectiveness of methods for removing denture adhesives from the surface of polymethylmethacrylate and printed resin**

*Removal denture adhesive from PMMA and printed resin*

Laianne Vieira Mendes, MSc [a], Manoela Borges e Souza Marques, DDS, [b], César Penazzo Lepri, PhD, [c], Denise Tornavoi de Castro, PhD, [d]

[(a)] Postgraduate student, Biomaterials Department, University of Uberaba, Uberaba, MG, Brazil. E-mail: dralainne@gmail.com

[(b)] Graduate student, Biomaterials Department, University of Uberaba, Uberaba, MG, Brazil. E-mail: manoelaborges@edu.uniube.br

[(c)] Adjunct Professor, Biomaterials Department, University of Uberaba, Uberaba, MG, Brazil. E-mail: cesar.lepri@uniube.br

[(d)] Adjunct Professor, Biomaterials Department, University of Uberaba, Uberaba, MG, Brazil. E-mail: denise.castro@uniube.br

Corresponding author:

Denise Tornavoi de Castro, Biomaterials Division/ University of Uberaba. Av. Nenê Sabino, 1801, 2D06 - Universitário – Zip Code: 38055-500. Uberaba, MG, Brazil. E-mail: denise.castro@uniube.br

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**ABSTRACT**

This study evaluated the properties of polymethylmethacrylate (PMMA) and printed resin, and the efficacy of denture adhesive removal methods. Sixty samples of each material were prepared. Roughness and wettability were measured. The samples were hydrated and weighed (W1). They were given 0.10 g of Ultra Corega cream and Fixodent adhesive and divided into three groups: chemical, mechanical and combined. The samples were reweighed (W2) and stained to quantify residual adhesive. The data were subjected to ANOVA and Bonferroni post-test ($\alpha$=5%). PMMA showed greater roughness ($p<0.001$) and hydrophobicity ($p=0.009$). The chemical method promoted a greater amount of residual adhesive (W2-W1) ($p<0.001$). There was less Corega on the printed resin and Fixodent on the PMMA. The printed resin had a larger area covered by adhesive ($p<0.001$). The combined method resulted in a smaller area covered by adhesive ($p<0.05$). There was a greater area of printed resin covered by Fixodent than PMMA when using the mechanical and combined methods ($p<0.05$). PMMA is rougher and more hydrophobic than printed resin. The mechanical and combined methods were more effective in removing the adhesive. The adhesives behaved differently on the materials, with Corega being easier to remove from the printed resin surface and Fixodent from PMMA.


**Keywords:** denture adhesive; polymethylmethacrylate; 3D printing resin; removal test; roughness; wettability.

## 3.1 INTRODUCTION

Conventional removable complete dentures are still the main treatment option for edentulous patients.[1] In the majority of cases, the materials used for manufacturing are acrylic resins based on polymethylmethacrylate (PMMA) due to their physical-mechanical properties.[2] However, there are disadvantages related to manufacturing defects, contraction of the polymerization, porosity, biofilm formation and long clinical time.[3-5]

Currently, digital methods for denture base production, including three-dimensional (3D) printing, are available.[6,7] This technique has become popular in dentistry with applications in surgical guides, provisional crowns, denture bases and implants.[8] The literature reports a high potential for 3D printing to modernize and speed up the manufacture of complete dentures.[9]

The success of a conventional denture depends on several factors, including the patient's previous experience of wearing dentures, the type of ridge and psychological aspects.[10] With age, systemic and oral factors, including multiple systemic illnesses, oral motor dysfunction, xerostomia due to drug side effects, ridge resorption, and mandibular deformity, often make dentures difficult to fit comfortably in the mouth.[11,12]

Denture adhesives are auxiliary agents in the retention and stability of dentures, increasing chewing performance and improving the quality of life of wearers.[12-14] However, incomplete removal from the denture surface or oral tissues is a problem with their daily use.[2] These materials must be completely removed during hygienization as a porous and rough denture base combined with residual adhesives can act as a reservoir for potentially infectious pathogens.[15-17] In addition, adhesive residue can affect the stability of the denture.[18]

Finally, as there are no studies that report on the use of denture adhesives on 3D printed base materials, it is questionable whether there is a difference in the ease of removal of the adhesive on these surfaces compared to PMMA. Thus, this study aimed to evaluate the surface characteristics (roughness and wettability) of PMMA and a 3D printed resin and the effectiveness of three hygiene methods in removing two adhesives applied to these materials. Null hypothesis are that there is no difference in resin roughness and wettability and that the hygiene method and denture adhesive type do not influence the ease of removal.

## 3.2 MATERIALS AND METHODS

The factors studied were the type of denture base resin (polymethylmethacrylate and 3D printing), the denture adhesive (Ultra Corega cream and Fixodent) and the hygiene methods (chemical, mechanical and combined). The quantitative response variable was the contact angle (Θ), surface roughness (µm), weight of residual adhesive (g) and the area of the sample that is covered by the adhesive (%). Figure 1 shows the study flowchart (Figure 1).

A total of 120 samples (10 x 10 x 2 mm) were obtained, of which 60 were heat-cured polymethylmethacrylate-based acrylic resin (Classical; Classical Dental Articles) and 60 were printed resin (Prizma Bio Denture; Makertech). For PMMA, the specimens were made in metal flasks and polymerization was performed (immerse in water at 73°C for 90 min and boil for 30 min) in a thermal cycler (Thermocycler T100). After disinclusion, the samples were finalized and stored in distilled water at 37ºC for 24 hours.[19] Printed samples were obtained using Digital Light Processing (DLP). Sample size data was entered into software and processed to produce a virtual drawing of the sample. The final design was imported into the printer software (FlashDLPrint). The printer contains a liquid resin reservoir, a full HD 1080 pixel resolution light projector and a Z-axis lift mechanism. After receiving the printed samples, post-processing procedures were carried out, including cleaning the samples with isopropyl alcohol for 5 minutes and post-curing in ultraviolet light for 10 minutes.

One of the sample surfaces was polished with water sandpaper (400, 800 and 1200 grit) and then with white of spain and a felt disc. The other surface of the specimen was left intact. The dimensions of the samples were checked using a digital pachymeter (Absolute, Mitutoyo Corporation, Tokyo, Japao).

The surface roughness of the polished and unpolished sides of 15 randomly selected samples from each group was analyzed using a surface roughness tester (Surftest SJ-201P, Mitutoyo Corporation, Tokyo, Japan). For each sample (n=10), three readings were taken at 0.5mm/s, 4.0mm long and 0.8mm cut-off.

Wettability was assessed using a goniometer (CAM200, KSV Instruments Ltd., Helsinki, Finland) by measuring the contact angle between the samples (n=10) and the water using the sessile drop method. For each sample, an average of three measurements was made with drops of deionized water containing a volume of approximately 4 μL (Milipore). The water droplet in contact with the substrate was allowed to partially stabilize for 60 seconds before a measurement was taken, according to the variation in the average angle (ϴ). The contact angle measurement was calculated by averaging the angle formed on the left and right sides of the drop from the images taken using the CAM 200 Contact Angle Measurement System software. The temperature was maintained at 24ºC during the tests.

The adhesives were removed according to the study by Polychronakis *et al.*, 2021[2], with some modifications (Figure 2). Samples were stored in distilled water in a 37°C oven for 24 hours before weighing and applying adhesive. After removal from the bath, the specimens were dried and the weight was recorded the following minute by the same researcher on a digital analytical balance.

After recording the weight of the specimens (W1), 0.10 g of Ultra Corega cream and Fixodent adhesives were applied to the unpolished surface of the specimens and pressed onto a silicone base measuring 15 × 15 mm and 2 mm thick, sprayed with Kin Hidrat artificial saliva (Pharmakin Cosmetics Ltda). The pairs (sample + silicone base) were then placed in an oven at a temperature of 37°C and a relative humidity of 95% for a period of 1 hour, removed from the oven and separated vertically.

The samples were then hygienized using the following methods:

Method 1- Chemical: Rinse under running water for 10 seconds and immerse in a 250 mL water bath at 40-45°C for 5 minutes with one tablet of Corega Tabs cleaner (GSK Consumer Health, Lincolnm Nebraska, United States).

Method 2 - Mechanical: Brushing with toothpaste for 1 minute.

Method 3 - Combined: Rinse under running water for 10 seconds and immerse in a 250 mL water bath at 40-45°C for 5 minutes with one tablet of Corega Tabs cleaner, then brush with solution for 1 minute.

In method 2, Colgate Maximum Caries Protection toothpaste (Colgate-Palmolive Industrial Ltda) was used. A solution was prepared 20 minutes before use by mixing toothpaste and distilled water 1:1. Brush used Oral-B Pro Series (Procter & Gamble, Germany) was applied at 2.0N (≈200g) for 1 min (166 vibrations/s). The paste solution was injected between the bristles every 15 seconds.

After hygiene, the samples were washed with distilled water and the polished surface dried with absorbent paper. They were then placed in an oven (37ºC) for 45 minutes to dehydrate the adhesive residue before the second weight measurement (W2).

After the second weighing, the samples were immersed in 1% neutral red dye (Gold Lab) for 5 minutes and photographed. The camera was placed on a tripod with the lens at 90 degrees to the surface of the specimen to obtain images of the recessed areas. The amount of adhesive remaining was quantified using Image J software.[17]

A 65 x 10 x 3 mm printed resin bar was used to record differences in water absorption and volume changes of the adhesives. 0.2 g of Ultra Corega cream and Fixodent were applied to the bar and sprayed with distilled water. The bar was placed in an oven at 37°C and 95% relative humidity for 180 minutes and removed for photography after 10, 60 and 180 minutes.[2]

SPSS software version 22.0 was used to analyze the data. After checking for normal distribution (Kolmogorov-Smirnov) and homogeneity (Levene), denture adhesive removal data were analyzed by three-way ANOVA. Surface roughness data were analyzed by repeated measures ANOVA and contact angle by one-way ANOVA. The

Bonferroni post-test was used ($\alpha = 0.05$). Pearson's Correlation Coefficient (r) was also used to evaluate the correlation among weight (g) and area (%) of adhesive remaining.

## 3.3 RESULTS

PMMA showed a greater contact angle (hydrophobicity) in relation to the printed resin ($p=0.009$) (Figure 3) and higher surface roughness ($p<0.001$). However, polishing was able to promote similar surface roughness on both materials ($p=0.820$) (Table 1).

When the factors of resin and denture adhesive type were considered separately, there was a statistical similarity in the total weight differences between the initially hydrated samples and after adhesive removal ($p>0.05$). However, there was a greater amount of adhesive remaining after rinsing with the chemical method compared to the mechanical and combined ($p<0.001$).

Table 2 shows the general weight differences between initially hydrated samples of PMMA and 3D printed resin before and after applying and removing adhesives by three different methods (chemical, mechanical and combined).

When using the chemical and combined hygiene methods, it can be seen that in PMMA the Fixodent values are lower than in Corega. On the other hand, Fixodent had higher values on printed resin than Corega after chemical hygienization.

The adhesives seem to behave differently on the denture materials, since Corega showed lower values on printed resin and Fixodent on PMMA.

When the resin type factor was considered separately, there was a significant difference in the area covered by the adhesive, with higher values for printed resin compared to PMMA ($p<0.001$). The combined hygiene method resulted in a smaller area (%) covered by the denture adhesive than the chemical and mechanical ($p<0.001$).

Table 3 shows the general differences in the area of denture materials (PMMA and 3D printed) covered by the adhesives (%) after removal by three different methods (chemical, mechanical and combined).

When using the chemical method, the area covered by Fixodent was greater for both resins. The area of PMMA covered by Fixodent was smaller than the area covered by Corega when the mechanical and combined methods were used.

The adhesives seem to behave differently on the denture materials since a greater area of the printed resin covered by Fixodent than PMMA was observed when using the mechanical and combined methods.

Pearson's correlation coefficient (r) showed that there was a moderate positive correlation between weight (g) and area (%) of adhesive remaining ($r = 0.359$). This indicates that an increase in one variable causes an increase in the other.[20]

Figure 4 shows that both denture adhesives expand with hydration, but Corega expands more than Fixodent. Fixodent shows signs of liquefaction, whereas Corega is still expanding after 180 minutes with fewer signs of liquefaction.

## 3.4 DISCUSSION

Saliva increases the viscosity of the adhesive in the buccal cavity before it spreads between the ridge and the denture. [17] This is responsible for their adhesive capacity; however, the American College of Prosthodontists' denture adhesive guidelines mention cleaning problems.[21] Therefore, the main strategies used to prevent these problems should focus on educating.

This study investigated the surface characteristics of two materials used to make denture bases, PMMA and 3D printed resin, and the amount of adhesive remaining after different hygiene methods. To analyze the amount of adhesive remaining, weight measurement was used[2] and the area covered was calculated using software.[17] Image processing has been widely used in engineering to analyze protocols or products. In adhesive removal, this protocol has already been used by some authors.[17, 22, 23]

The hypotheses that there were no differences in the roughness and wettability of the resins, or that hygiene protocols and the type of denture adhesive had an effect on ease of removal, were rejected.

Fixodent was easier to remove using mechanical and combined methods than Corega. Corega continued to expand 180 minutes after wetting, whereas Fixodent showed more signs of liquefaction. This may be due to a higher water insoluble component in Corega. The findings indicated that brushing with toothpaste and immersion with Corega Tabs combined with brushing with the solution itself, facilitated the removal of denture adhesives. A 5-minute immersion in Corega Tabs alone produced the worst results. This shows that daily cleaning with a mechanical brush is essential. Effective removal of adhesives required immersion in denture cleaner for more than 12 hours, which is extremely long for daily use, according to Harada-Hada *et al*, 2016[22]. These findings corroborate a previous study which indicated that the combined cleaning technique, which includes both mechanical abrasion and chemical agents, results in better removal of residues.[17]

Although the mechanical and combined methods promoted better removal of denture adhesive, as evidenced by the difference in weight, they did not promote complete removal. When observing the covered area, it can be seen that there was still adhesive covering the surface. A clinical study evaluating hygiene methods using an image processing system was conducted by Nunes *et al*., 2016.[24] They found that water brushing alone was insufficient, the most effective methods being soap brushing, toothpaste brushing and brushing after immersion in sodium perborate solution. Using these methods, they found that 2-5% of the dentures still had adhesive.[25]

The PMMA surface, especially when unpolished, was rougher, which could facilitate the adhesion of residual adhesive, as indicated by a study associating surface roughness with residue retention.[26] After polishing, the surfaces of the two resins showed similar roughness. Differences between resins were found significantly with adhesives. Independently, the greater presence of adhesive residues on the surface of the printed resin cannot be explained by the roughness, as PMMA had the roughest surface. The greater affinity of the adhesive components for the printed resin is one explanation since it has a more hydrophilic surface. Poker *et al*., 2024[27] also found that the conventional resin had a greater contact angle than the 3D printed resin. Furthermore, the different behavior of the adhesives on different materials, with Fixodent being more easily removed from PMMA and Corega from printed resin, highlights the importance of considering both the properties of the adhesive and the properties of the material used to fabricate the denture base when selecting the appropriate adhesive for clinical use. The interaction between the adhesive and the oral substrate can significantly influence the effectiveness of debris removal, which reinforces the need for further studies investigating these specific interactions.[8,14]

Our results suggest that the immersion time for daily treatments should be reconsidered. Our experiments showed that 5 minutes in the denture cleaner was not enough to remove the adhesive cream, so other daily treatments, like mechanical cleaning, are needed. Another question is which adhesive makes cleaning easier. The adhesives behave differently on the denture base materials. Fixodent covers a larger area of printed resin than PMMA when the mechanical and combined methods are used. Fixodent and the combined hygiene technique gave the best removal results, especially when the denture was made of PMMA.

The hygiene protocol can be standardized, but there are limitations. In vitro studies can't simulate how patients carry out the protocol, and the samples used are small. The adhesives undergo changes in the mouth, and the materials remained in the bath for a long time. One hour was enough for the measurements, but 12 or 24 hours are more realistic. A clinical study would be better for answering questions.

Dentures need cleaning, even with a simple method, because microorganisms on the inner surface of the denture base can cause inflammation. Chemical methods, such as peroxide cleaners, were not effective at removing adhesives. The methods depended on the material and adhesive. The adhesive could not be complete removed from the resins' surfaces, so new methods are needed to improve the quality of life for denture adhesive users.

## 3.5 CONCLUSION

It can be concluded that the surface of PMMA is rougher and more hydrophobic than that of printed resin, and that polishing promotes similar roughness. The mechanical and combined methods were more effective in removing the adhesive. The adhesives behaved differently on the materials as Corega was more easily removed from the printed resin surface and Fixodent from PMMA.

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## 3.7 TABLES

**Table 1.** Mean and standard deviation of surface roughness (µm) of denture base resins before and after polishing.

| Material | Unpolished | Polished |
|---|---|---|
| **PMMA** | 3.42(0.80)Aa | 0.27(0.19)Ab |
| **Printed resin** | 1.26(0.62)Ba | 0.25(0.12)Ab |

Same capital letters indicate non-significant differences (p>0.05) between cells in the same column and lowercase letters between cells in the same row (n=15).

**Table 2.** Mean and standard deviation of the weight (g) of remaining adhesive, considering the interaction between type of resin x type of adhesive x hygiene method.

| **Hygiene** | **Resin** | **Denture adhesive** | |
|---|---|---|---|
| **Method** | **Material** | **Corega** | **Fixodent** |
| **Chemical** | PMMA | 0.166 (0.035)Aa | 0.129(0.052)Ab |
| | Printed resin | 0.117(0.068)Ba | 0.196(0.030)Bb |
| **Mechanical** | PMMA | 0.009(0.008)Aa | 0.008(0.010)Aa |
| | Printed resin | 0.022 (0.012)Aa | 0.006(0.004)Aa |
| **Combined** | PMMA | 0.036(0.026)Aa | 0.001(0.003)Ab |
| | Printed resin | 0.025 (0.019)Aa | 0.011 (0.025)Aa |

The same capital letters indicate non-significant differences (p>0.05) between cells in the same column within each hygiene method. Lower case letters indicate non-significant differences between cells in the same row (n=10).

**Table 3.** Mean and standard deviation of the area covered (%) by the remaining adhesive, considering the interaction between type of resin x type of adhesive x hygiene method.

| **Hygiene** | **Resin** | **Denture adhesive** | |
|---|---|---|---|
| **Method** | **Material** | **Corega** | **Fixodent** |
| **Chemical** | PMMA | 67.20(8.60)Aa | 82.09(14.92)Ab |
| | Printed resin | 58.84(18.47)Aa | 92.83(6.92)Ab |
| **Mechanical** | PMMA | 84.18(10.46)Aa | 40.20(19.57)Ab |
| | Printed resin | 84.65(11.00)Aa | 88.72(5.32)Ba |
| **Combined** | PMMA | 56.82(18.61)Aa | 10.22(13.76)Ab |
| | Printed resin | 56.60(25.37)Aa | 63.01(20.12)Ba |

The same capital letters indicate non-significant differences ($p>0.05$) between cells in the same column within each hygiene method. Lower case letters indicate non-significant differences between cells in the same row (n=10).

## 3.8 FIGURES

**Figure 1.** Study flowchart.

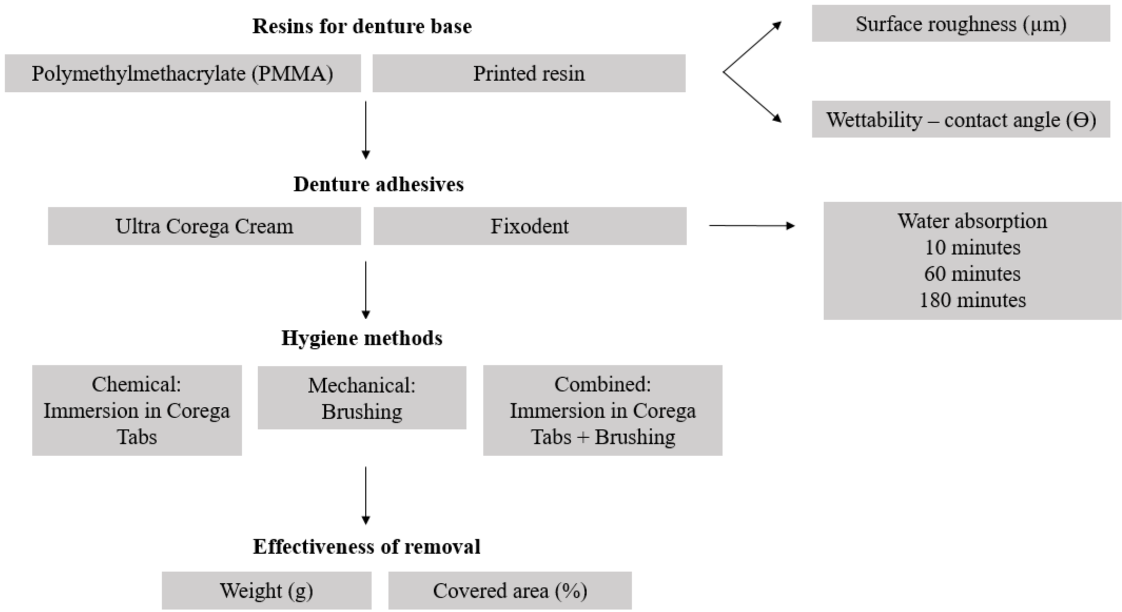


**Figure 2.** Test of adhesive removal from the surface of PMMA and printed resin by weighing and calculating the area covered by the remaining adhesive.

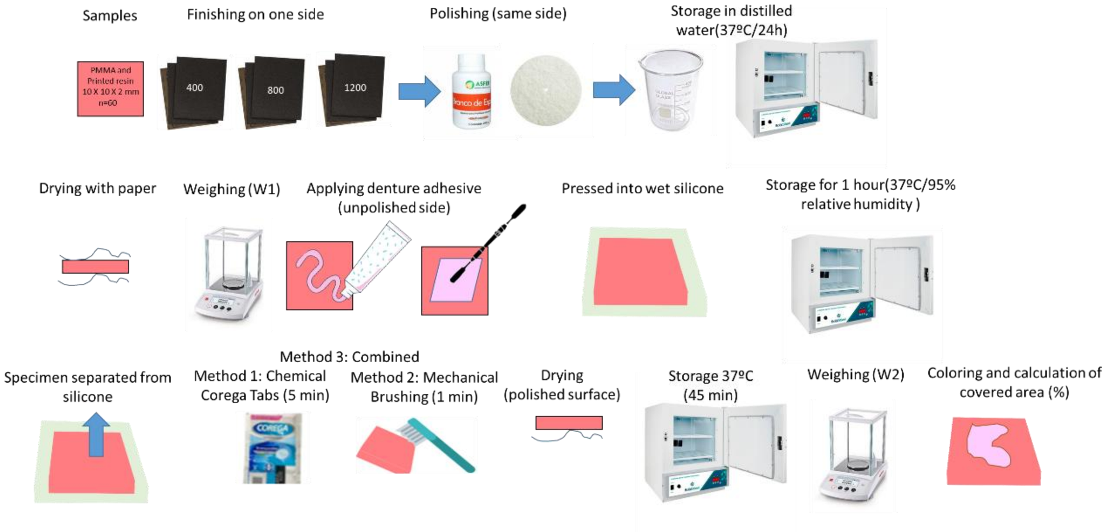


**Figure 3.** Mean and standard deviation of the contact angle (ϴ) of the resins. *Different letters indicate statistical difference ($p < 0.05$) and representative images: A) polymethylmethacrylate (PMMA)-based heat-cured resin ; B) printed resin.

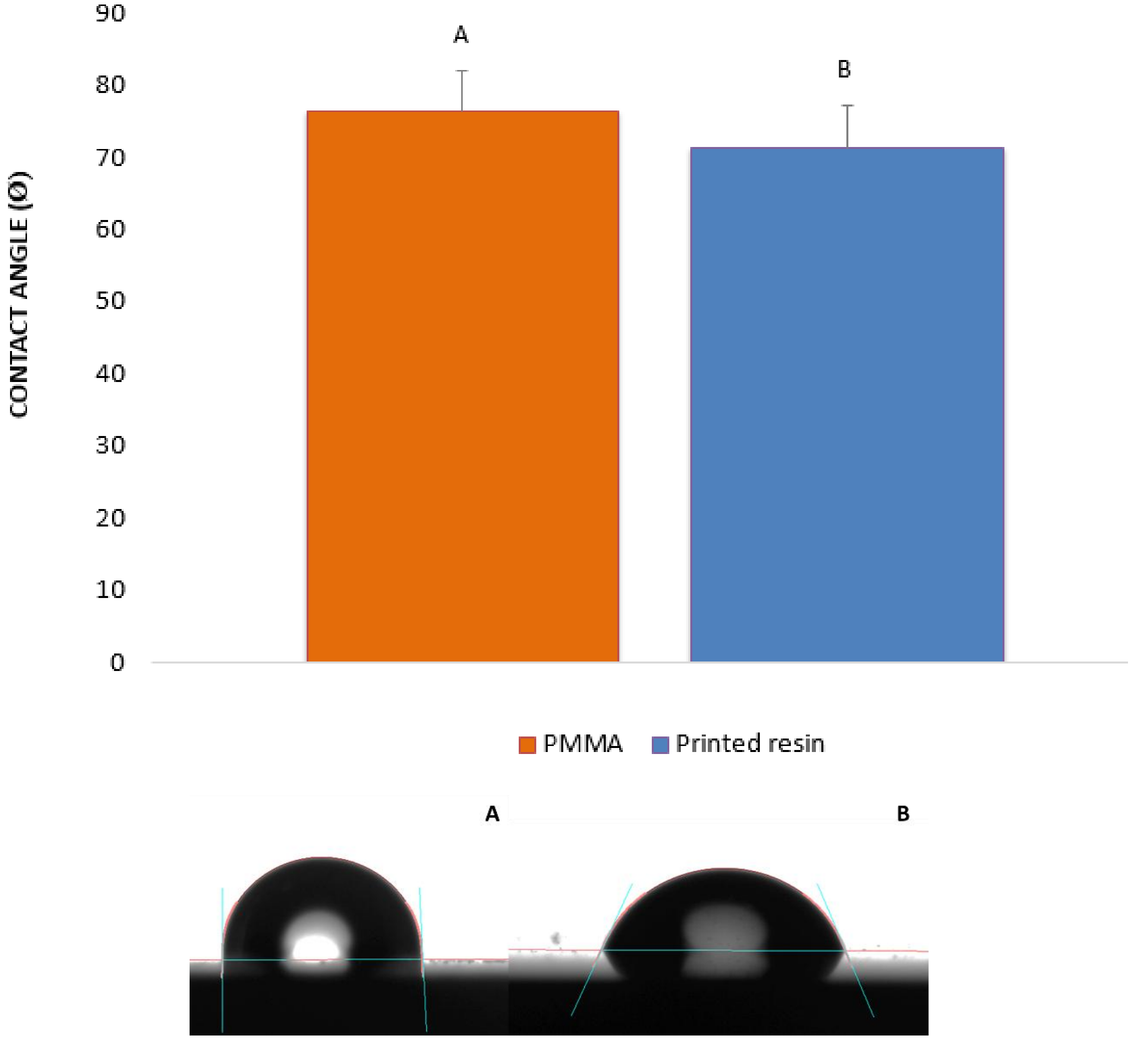
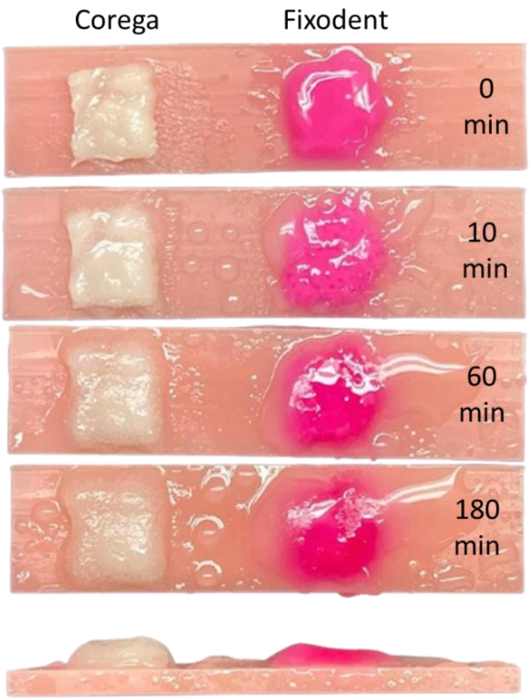


**Figure 4.** Hydration test of Corega and Fixodent adhesives, initial image, after 10 minutes, after 60 minutes and after 180 minutes.



# *4 CONCLUSÃO*

Conclui-se que a superfície do PMMA é mais rugosa e hidrofóbica do que da resina impressa, e o polimento promove rugosidade semelhante aos materiais. Os métodos mecânico e combinado foram mais efetivos na remoção do adesivo. Os adesivos se comportaram de forma diferente nos materiais uma vez que o Corega foi mais facilmente removido da superfície da resina impressa e o Fixodent do PMMA.

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# *APÊNDICES*

**Figura 1.** Etapas da confecção dos corpos de prova em resina acrílica termopolimerizável


**Figura 2.** Impressão das amostras na impressora Flashforge Hunter 3D Printer

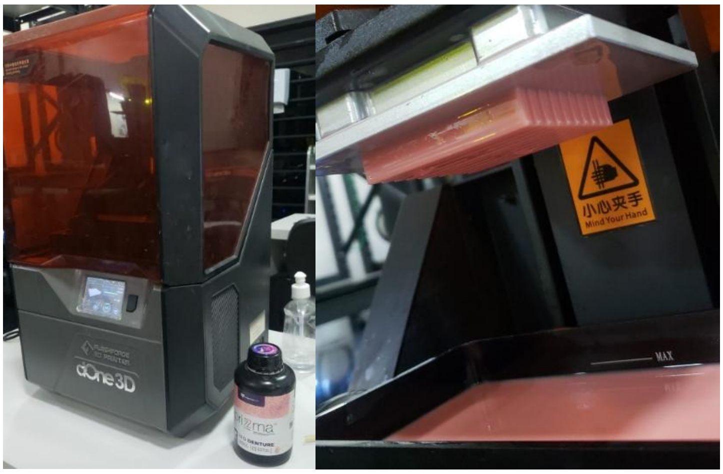

**Figura 3.** Análise da rugosidade superficial das amostras em rugosímetro


**Figura 4.** Análise da molhabilidade das amostras em goniômetro

**Figura 5.** Análise da remoção dos adesivos

**Figura 6.** Amostras imersas em corante e quantificação do adesivo remanescente no Software Imaje J.

**Figura 7.** Média e desvio padrão do peso (g) do adesivo remanescente, considerando o fator tipo de resina individualmente.

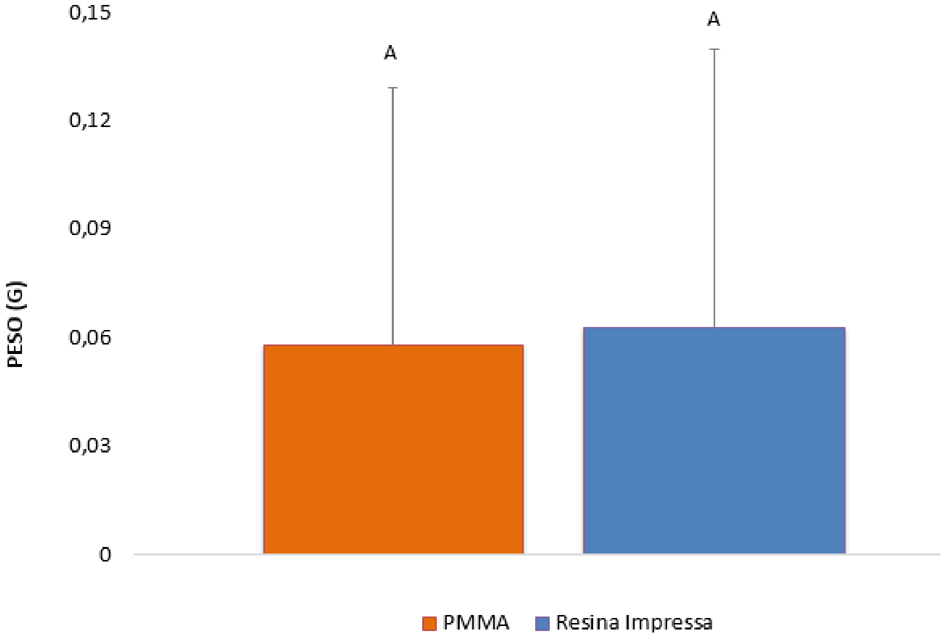


**Figura 8.** Média e desvio padrão do peso (g) do adesivo remanescente, considerando o fator tipo de adesivo individualmente.

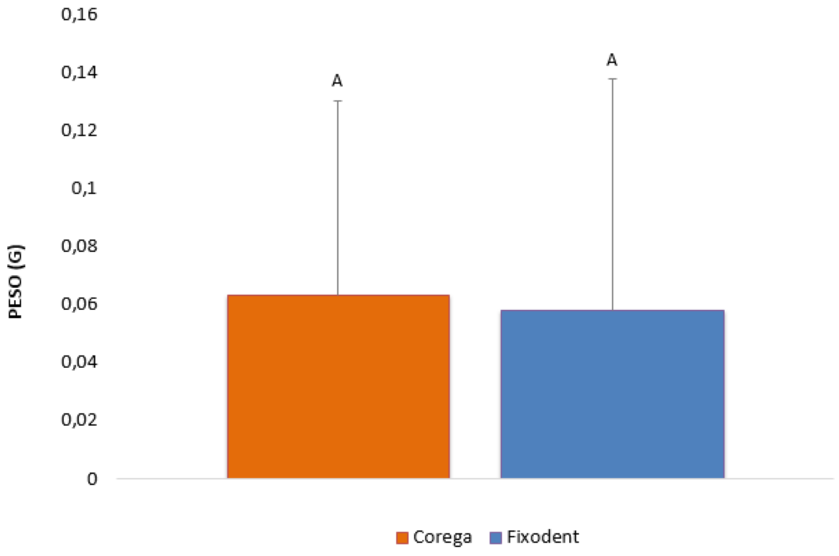

**Figura 9.** Média e desvio padrão do peso (g) do adesivo remanescente, considerando o fator tipo de adesivo individualmente.

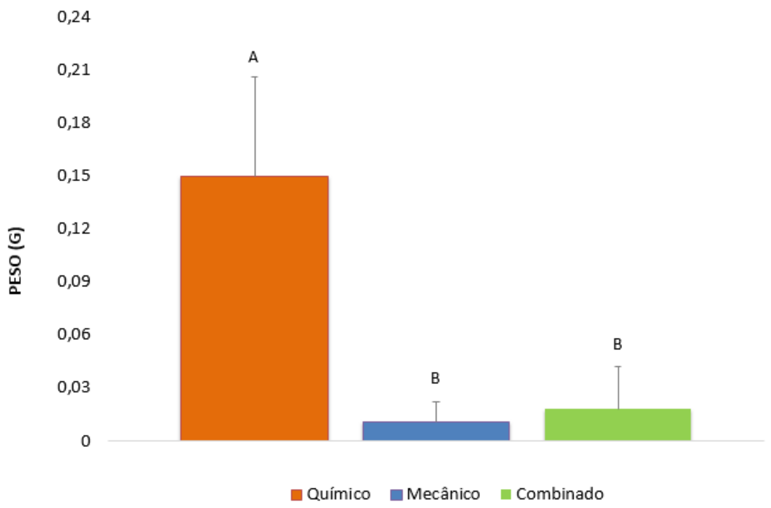


**Figura 10.** Média e desvio padrão da área recoberta (%) pelo adesivo remanescente, considerando o fator tipo de resina individualmente.

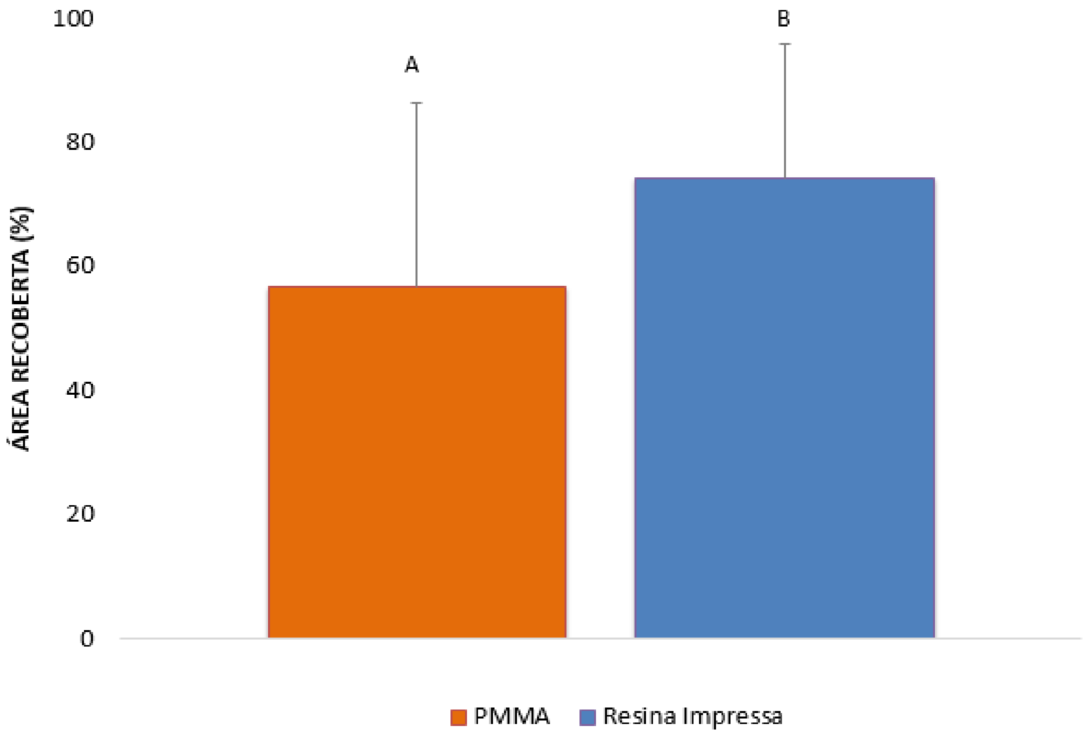

**Figura 11.** Média e desvio padrão da área recoberta (%) pelo adesivo remanescente, considerando o fator tipo de adesivo individualmente.

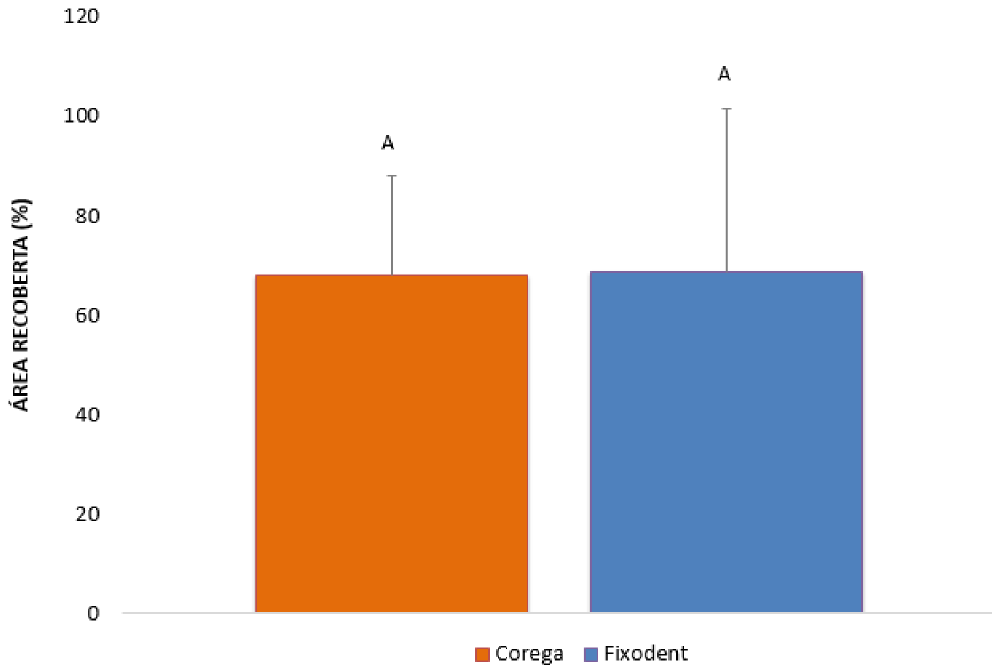


**Figura 12.** Média e desvio padrão da área recoberta (%) pelo adesivo remanescente, considerando o fator método de higiene individualmente.