

Térsia Cristina Silva Macêdo

Cantilever flexural resistance of temporary implant-supported complete prosthesis manufactured from different materials.

Resistência flexural em cantiléver de prótese total
implantossuportada provisória confeccionada em diferentes
materiais

Dissertação apresentada à Faculdade
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Orientadora: Profª Dra. Karla Zancopé

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Profº Dr. Carlos José Soares

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RESUMO

O cantilever é utilizado em próteses implantossuportadas, resultando em um ponto de vulnerabilidade sob cargas oclusais, principalmente no caso de próteses imediatas e/ou provisórias. O objetivo do estudo foi avaliar a resistência à flexão na região cantilever de próteses provisórias implantossuportadas, fabricadas sobre minipilares cilíndricos, utilizando três diferentes tipos de resinas. As unidades experimentais foram constituídas por próteses implantossuportadas com cantilever de 15mm e 3 níveis de resinas acrílicas: resina autopolimerizada convencional (RA); resina termopolimerizada (RD) de alta resistência; e resina protética convencionalmente termopolimerizada (RT) com estrutura metálica. Materiais e Métodos: foram realizados ensaios de resistência à flexão e deflexão para determinar a carga suportada na região do cantilever e os valores máximos de deslocamento das amostras. A análise estatística foi realizada utilizando ANOVA seguida do teste de Tukey, assumindo $\alpha = 0,05$ (Jamovi, The Jamovi Project Versão 2.4). Foram detectadas diferenças significativas entre todos os grupos ($P < 0,001$): RA 396 N, RD 440 N. e RT 553 N. Maiores valores de deformação do grupo RD (5,07 mm), seguido pelo grupo RT (3,93 mm) e grupo AR (3,37 mm). Dentro das limitações do presente estudo, as resinas acrílicas de alto impacto demonstraram desempenho mecânico que sugerem ser uma opção viável para próteses totais provisórias sobre implantes, apresentando comportamento mecânico superior quando comparadas às resinas convencionais confeccionadas com resina acrílica.

Palavras-chave: cantilever, implante, resistência à fratura, restaurações provisórias.

ABSTRACT

Cantilever is used in implant-supported prostheses, resulting in a point of vulnerability under occlusal loads, particularly in case of immediate and/or provisional prostheses. The aim of this study was to evaluate the flexural resistance in the cantilever region of provisional implant-supported prostheses, fabricated over mini abutments cylinders, using three different types of resins. The experimental units consisted of implant-supported prostheses with a 15mm cantilever and 3 levels of resins: conventionally auto-polymerized resin (RA); high resistance thermo-polymerized resin (RD); and conventionally thermo-polymerized denture resin (RT) with metallic structure. Materials and Methods: flexural strength and deflection tests were carried out to determine the load supported in the cantilever region and the maximum displacement values of the samples. Statistical analysis was performed using ANOVA followed by Tukey's test, assuming $\alpha=0.05$ (Jamovi, The Jamovi Project Version 2.4). Significant differences were detected among groups ($P < 0.001$): RA 396 N.cm, RD 440 N.cm and RT 553 N.cm. RD group highest deflection values (5.07 mm), followed by RT group (3.93 mm) and RA group (3.37 mm). In the limitations of the present study, high-impact resins could be a viable option for provisional implant – supported full prostheses, presenting superior mechanical behavior when compared to conventional prosthesis made with acrylic resin.

Key words: cantilever, implant, fracture resistance, interim restorations.

1. Introdução e Referencial Teórico

A introdução dos implantes dentários osseointegrados revolucionou as abordagens protéticas, emergindo como uma alternativa essencial para a melhoria da qualidade de vida dos pacientes que perderam alguns ou todos os dentes ao decorrer da vida (Cristina et al., 2022). As próteses fixas são dispositivos protéticos que contam com estabilidade e retenção e são suportados por implantes dentários. Essas próteses têm sido empregadas por mais de trinta anos (Minoretti et al., 2012; Takaba et al., 2013; Cristina et al., 2022; Mendes et al., 2022.). No entanto, em alguns casos durante a reabilitação fixa implantossuportada temos que considerar o uso de cantiléveres devido às condições anatômicas e morfológicas dos pacientes (Minoretti R., et al 2012). Resulta na confecção de elementos protéticos, provisórias ou definitivos, com um ponto de fragilidade para suportar as cargas oclusais (Brånemark et al., 1999; Rues et al, 2020)

As restaurações provisórias desempenham um papel fundamental no tratamento odontológico, Durante o período em que a prótese provisória é instalada os testes funcionais e estéticos são realizados e ajustes são feitos para que assim possa ser possível e avaliar o desempenho que a prótese final (Sing et al., 2016.)

Durante a seleção dos materiais para confecção destas restaurações, os cirurgiões dentistas devem considerar as propriedades físicas, a facilidade de manuseio, o custo e a satisfação e aprovação do paciente (Burns et al., 2003). Durante a fase de provisório fraturas na região do cantiléver podem ser desencadeadas pela tensão exercida durante a mastigação ou por hábitos parafuncionais, o que pode levar à falha da prótese. É comum a necessidade de reparos nesse tipo de prótese, sendo a resina acrílica o material mais comumente utilizado na fabricação de próteses dentárias devido à sua estética, facilidade de manipulação e custo acessível. No entanto, é importante observar que esse material apresenta resistência mecânica relativamente baixa, o que pode aumentar o risco de fraturas da prótese, podendo gerar micromovimentos

que interferem na osseointegração. (Angelara et al., 2021). O que pode acarretar na perda da prótese e do implante.

A fratura de próteses provisórias fabricadas de resina acrílica é um desafio, pois essa falha é resultante de uma combinação de fatores (Gupta. & Tewari et al., 2016). Podendo ser por motivos de alta força de mordida do paciente, prótese desajustada, hábitos parafuncionais, assim é crucial compreender os princípios relacionados às propriedades mecânicas dos materiais constituintes garantir um desempenho satisfatório da prótese (Abad-Coronel C., et al 2021). Parâmetros como quantidade de força, deformação, deflexão, podem ser utilizados para avaliar as características de um material. (Lodding et al., 1997 Gupta A. & Tewari R et al., 2016;)

No melhor conhecimento dos autores, é escasso a disponibilidade de estudos que avaliam e comparam o comportamento biomecânico de próteses provisórias implantossuportadas sobre cantiléver confeccionadas a partir de diferentes materiais, decidimos utilizar para os testes em laboratório um grupo com resinas acrílica de alto impacto, para verificar e comparar sua força máxima, deflexão e deformação comparando-a com as resinas já consolidadas no mercado.

A hipótese nula do presente trabalho é que não há diferença no comportamento mecânico das próteses provisórias em cantiléver implanto suportadas, independente do material de fabricação.

2. CAPÍTULO 1

ARTIGO

Cantilever flexural resistance of temporary implant-supported complete prosthesis manufactured from different materials.

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Cantilever flexural resistance of temporary implant-supported complete prosthesis manufactured from different materials.

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Cantilever flexural resistance of temporary implant-supported complete prosthesis manufactured from different materials.

Abstract

Statement of problem: Cantilever is used in implant-supported prostheses, resulting in a point of vulnerability under occlusal loads, particularly in case of immediate and/or provisional prostheses.

Purpose: The aim of the study was to evaluate the flexural strength at the cantilever region of provisional implant-supported prostheses, fabricated over mini abutments cylinders, using three different types of resins. The experimental units consisted of implant-supported prostheses with a 15mm cantilever and 3 levels of resins: conventionally auto-polymerized resin (RA); high resistance thermo-polymerized resin (RD); and conventionally thermo-polymerized denture resin (RT) with metallic structure.

Materials and Methods: flexural strength and deflection tests were carried using universal test machine and deflectometer (Instron) to determine the supported in the cantilever region and the maximum displacement values. ANOVA followed by Tukey's test.

Results: Significant differences were detected among groups ($P < 0.001$): RA 396 N.cm, RD 440 N.cm and RT 553 N.cm. RD group highest deflection values (5.07 mm), followed by RT group (3.93 mm) and RA group (3.37 mm).

Conclusion: In the limitations of the present study, high-impact resins could be a viable option for provisional implant – supported full prostheses, presenting superior mechanical behavior when compared to conventional prosthesis made with acrylic resin.

Clinical Implications:

High-impact thermopolymerizable resins were specifically formulated to be employed in short-term supported implant prostheses. This design aims to achieve a reduction in costs without compromising the quality of treatment for patients with impossibility to perform the definitive implant-supported rehabilitation.

Introduction

Edentulism is an oral condition that impacts on health of individuals who have lost teeth. This condition has implications for nutrition,¹ aesthetics,² and self-esteem,³ thereby diminishing the overall quality of life.⁴ The low and medium-income countries, like Brazil exhibits high rates of edentulous patients, with the elderly population being the fastest-growing group, expected to continue increasing until 2040, reaching over 37 million individuals.⁵ Consequently, the number of edentulous jaws will rise, surpassing 64 million by 2040.⁶ With the global elderly population expanding, 400 million seniors will be reached by 2050, leading to an increased prevalence of partial or total edentulism.⁷ For treating treatment of edentulism, complete dentures are recommended due to their stability and retention, achievable through dental implants.

Dental implants are considered the treatment option for replacement of missing teeth due to their high success rates, reliable prosthetic treatment, and diverse applications in dentistry.^{8,9} In temporary implant-supported rehabilitations, an important point of vulnerability is the distal region of the mandible.¹⁰ In this area, anatomic conditions do not allow the placement of implants at the most distal region of the prosthesis, and a cantilever must be designed. Consequently, occlusal loads can generate the high stress and strain at this location causing the fracture the distal of prosthesis.^{11,12}

The determination of bite force is a crucial parameter in assessing the function and efficacy of dental prostheses and orthodontic treatments, as well as in studying the impact of deformities and pathologies such as malocclusion and overload on the masticatory system.^{13,14} It has been observed that implants-supported prostheses exert higher levels of bite force compared to root-retained or complete dentures.¹⁵, occlusal overload may contribute to implant¹⁶ or prosthesis failure, as the force applied may surpass the load-bearing capacity of the selected rehabilitation material. Mean values for the maximum bite force pattern range from 859 N¹⁷ to 430.4 N,¹⁸ for non-bruxist patients.

The placement of a temporary implant-supported prosthesis is an intermediary treatment to protect periodontal tissues, promote guided tissue healing, properly manage emergence profiles, evaluate patient hygiene procedures.^{19,20} Temporary prostheses must withstand an occlusal load throughout the osseointegration process, which can last from 4 to 6 months.²¹ Temporary implant-supported prosthesis must be manufactured using materials, that present mechanical properties to resist the tissue

healing period and osseointegration process.^{21,22} Fractures in cantilevered region may occur due to stress and strain during chewing or parafunctional habits, causing failure of the prosthesis during healing phase. Frequently, repairs need to be made, and conventionally auto-polymerized resins are the most widely used material due to its aesthetics, easy manipulation, and low cost. However, this material has relatively low mechanical resistance, which could cause fracture of the prosthesis,²³ resulting in micromovements that should be avoided during osseointegration process.^{12 21 24.}

It is important to understand the mechanical behavior of dental materials, such as their resistance to fracture and deflection.²⁶ On the best of the author's knowledge the biomechanical behavior of these temporary implant-supported prostheses made from different materials. Therefore, the aim of the present study was to evaluate the flexural strength and deflexion in the cantilever region of provisional implant-supported prostheses. The null hypothesis was that the in mechanical behavior of the cantilevers of supported implant provisional prostheses, irrespective of manufacturing material.

Materials and Methods

This study was an in vitro laboratory test. Experimental unit consists of provisional implant-supported prostheses with distal cantilever (n = 10), in 3 levels: Ra group, auto-polymerized resin (VIPI Flash – Self-curing acrylic resin), as the control group; RD group resistance thermo-polymerized resin (Diamond D Thermocuring Acrylic Resin, Keystone), as the tested group; and RT group, thermo-polymerized denture resin (VIPI Cril Plus, thermopolymerizable acrylic resin, VIPI) with Nickel chromium infrastructure (Wironia light, BEGO), as the positive control group.

Obtention of support

This metallic support was designed to perfect fit at the universal testing machine (Instron, Instron Brazil), allowing to perform all tests. A metal support was made from aluminum with dimensions of 90 mm long by 70 mm wide and 12 mm high. In the center of the base, a square structure 25 mm wide, 25 mm long and 35mm high, was machined (Figure 1). Two perforations were made to place 2 analogues of dental implants (GM 4.1, Neodent) positioned 1 cm equidistantly. Two abutments (mini abutments, 1.5, Neodent) were placed in their respective analogue, with torque recommended by manufacturer. Then, the transfers were screwed over the abutments, forming an index, to transfer the exact position of the analogues.

RT group

With the index screwed on its metal base, the positive control group was obtained. The position of the mini abutments was scanned (InEos X5, Dentsply Sirona), and the design of the metal bar were performed (EXOCAD, Align Technology). Each bar has total length of 35 mm, 4 mm of thickness and 15mm of cantilevered size (Figure 2A). Another rectangular bar was designed (EXOCAD, Align Technology), with 10mm wide and 8mm high (Figure 2B and Figure 2C). From the CAD drawings, 10 bars of the infrastructure and the rectangular bases were 3D printed (Anycubic; Texas Instruments) (Figure 3). The bars followed the conventional casting process, captured, included, and cast, lost wax technique, with nickel chromium metal alloy (Wironia light, BEGO).

The bars were positioned in the resin pattern with the final shape of the resin base, surrounding the metal bar. The process of inclusion in muffle were conventionally performed. (type IV dental stone, DentMix Type IV Special Stone, Asfer). Six samples were positioned each time inside the muffle. (Figure 4).

The thermo-polymerized resin was placed over the space left by the printed resin bars, (Figure 4) and the polymerization was performed (microwave oven: 1200 to 1400 Wats; initial stage: 20 minutes with 10/20% power; and final stage: + 5 minutes with 30/40% power). Finishing and polishing was carried out on all samples.

Resin groups without metal infrastructure (RA group and RD group)

The titanium cylinders (GM mini abutments 4.1, Neodent) were captured over the implant analogues (GM analogue implant 4.1, Neodent) and included in the muffle, as described above. The polymerization cycles used for each resin are as follows (Figure 5):

- RD group: high resistance thermo-polymerized resin (Diamont D resin, Keystone industries). Ten ml of monomer to 21 g of powder, by weight. The microwave cycle was performed, with 4 minutes at 700 W of power, to polymerize the parts. Finishing and polishing was carried out on all samples.

- RA group: conventionally auto-polymerized resins (Self-curing acrylic resin, VIPI). Two portions of powder to 1 portion of liquid (14g of powder to 7 ml of liquid) were poured into a glass jar and homogenized carefully with a spatula. For polymerization, the resin was taken to a polymerizer with water, apply 20 pounds of compressed air and let the polymerization complete for 20 minutes to open the muffle, remove the parts, and perform the finishing and polishing. Finishing and polishing was carried out on all samples (Figure 6A).

Flexural Strength Test

The metal base assembly and each structure (Figure 7) were tested using the universal testing machine Eletropulse 3000 (Instron), for fracture. A rounded piston was positioned at 5 mm from the end of the specimen, simulating biting over the cantilever. An axial and progressive load was applied until fracture, and the maximum value of resistance of each part and displacement were obtained. In the lower part of the cantilever, a deflectometer was positioned to measure the displacement at the moment of fracture.

Statistical analysis

Data were first analyzed for normal distribution (Shapiro-Wilk test) and homoscedasticity (Levene's test). Then, a one-way analysis of variance followed by Tukey post-hoc tests to compare the flexural strength (N) and deflexion (mm) data. All tests used $\alpha = 0.05$ significance level, and all analyses were carried out with the statistical package (JAMOV, The Jamovi Project Version 2.4)

Results

The maximum load to failure (N) and the deflexion at the fracture are shown in Table 1. There was a significant difference between auto-polymerized resin (RA); high resistance thermo-polymerized resin (RD) and conventionally thermo-polymerized denture resin (RT) groups ($P < 0.05$). RD group presented lower flexural strength values (440 N.cm) when compared to RT group (553 N.cm), and RA group presented lower flexural strength values (396 N.cm) when compared to RD group (440 N.cm) according to Table 1 and Figure 8.

According to Figure 9 e 10, these graphs show us the Bending Displacement at maximum force and the Deflection at maximum force, in which we see how the piston moved downwards, demonstrating that the high impact acrylic resin has a greater displacement compared to the other two resins. The RD presents a significantly greater deformation before the fracture occurs, in the two factors observed this is also seen in Table 1.

All samples were photographed, and the fracture mode was analyzed. All fractures occurred at the distal cylinder abutment (Figure 11).

Discussion

The null hypothesis of the present study was rejected, since differences were detected in the mechanical behavior of the provisional implant supported prostheses with distal cantilevers, depending on the material.

In all groups, failures predominantly occurred in the distal part of the abutment cylinders. This outcome aligns with expectations and is a common phenomenon in failures,²³ due to the absence of posterior reinforcement. This type of fracture was already observed, where the point of force concentration is distant from the distal component,²³ fractures ensue through the slender lateral walls of the screw capture hole in the furthest part of the distal component.²² In the absence of a metal bar to reinforce the prosthesis, and the repair is unfeasible, because the resin becomes entirely detached. If the dentist chooses an implant-supported provisional prosthesis made of autopolymerizing acrylic resin (RA) only and the patient exhibits a high bite force, maybe the material is not appropriate, due to the mean bite force to be 430,4 N (Van Vuuren et al.). So, the risk of fracture with this material may be deemed high, given that the average for the RA group was 396 N.

The use of temporary prosthesis manufactured with self-polymerizing acrylic resin, whether due to the benefits it brings in terms of aesthetics, ease of manipulation and low cost, this material is not recommended due to its mechanical resistance being relatively low, which may cause the prosthesis to fracture (Asar NV et al. 2013). This data is in line with our study, as the parts made from acrylic resin were the ones that obtained the worst result in relation to the force supported.

According to the results obtained in this study, the use of high-impact resins is preferable, when the patient does not have the financial condition²² to perform the final rehabilitation just after the implants' placement. This resin exhibits higher force support, considering that the average bite force is 430.4 N.¹⁸ The high-impact resin performs better as it not only withstands an average force of 440 N but also has high deflection, aiding in visualizing if the prosthesis is under excessive force. During tests, the RD group showed areas with different colors, indicating the possible site experiencing overload; the area shows whitish before the fracture (Figure 12). Thus, it is expected to observe, during follow-up appointments, whether the distribution of occlusal forces is appropriate or if any adjustments are needed.

RD group demonstrated to be more resistant and with a faster thermopolymerizable time, when compared to RA and RT groups. This high impact acrylic resin avoids the need for metal palatal reinforcement structures, dispenses the rest

period after inclusion (could be polymerized immediately after inclusion), and the microwave cycle could be used during only 4 minutes. Its application includes total dentures, acrylic implant supported prosthesis and partial dentures. In the present study, unpredictability in the behavior of the conventional acrylic resin (RA) group was observed, due to its high standard deviation. Furthermore, its laboratory processing steps are slower, and its polymerization takes longer, requiring 20 minutes for complete polymerization, to start finishing and polishing (manufacturer's recommendation).

At the dental office, both theoretically and based on obtained results, the use of high-impact resins appears to increase the process of implant immediate loading due the placement of a temporary prosthesis. The present study suggests that, with the proper distribution of occlusal forces, the use of high-impact resins in provisional prostheses may contribute to enhanced longevity. This is particularly beneficial in cases requiring an extended healing period for complete osseointegration, for treatment with excellent results.

Conclusion

With the limitations of the present study, some conclusions could be draw:

- 1- RA group showed a lower mechanical behavior when compared to the other groups;
- 2- The RD group presented lower values of maximum supported force when compared to the RT group and higher values when compared to the RA group;
- 3- The use of high-impact resins could be a good alternative, due to greater deflection before complete fracture;
- 4- High-impact resins could bring agility to the process of implant immediate loading.

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Table

	Groups	Maximum Strength	Bending displacement at maximum force	Deflection at maximum force
Medium	RA	396 Ncm	2.37 mm	2.00 mm
	RD	440 Ncm	5.07 mm	3.81 mm
	RT	553 Ncm	3.93 mm	3.03 mm

Table 1- Conventionally auto-polymerized resin (RA); high resistance thermo-polymerized resin (RD); and conventionally thermo-polymerized denture resin (RT) with metallic structure.

Descriptive analysis of data of bending moment, bending displacement at maximum force and deflection at maximum force

Figures e Legends



Figure 1 metal base with analogues and mini pillars in position

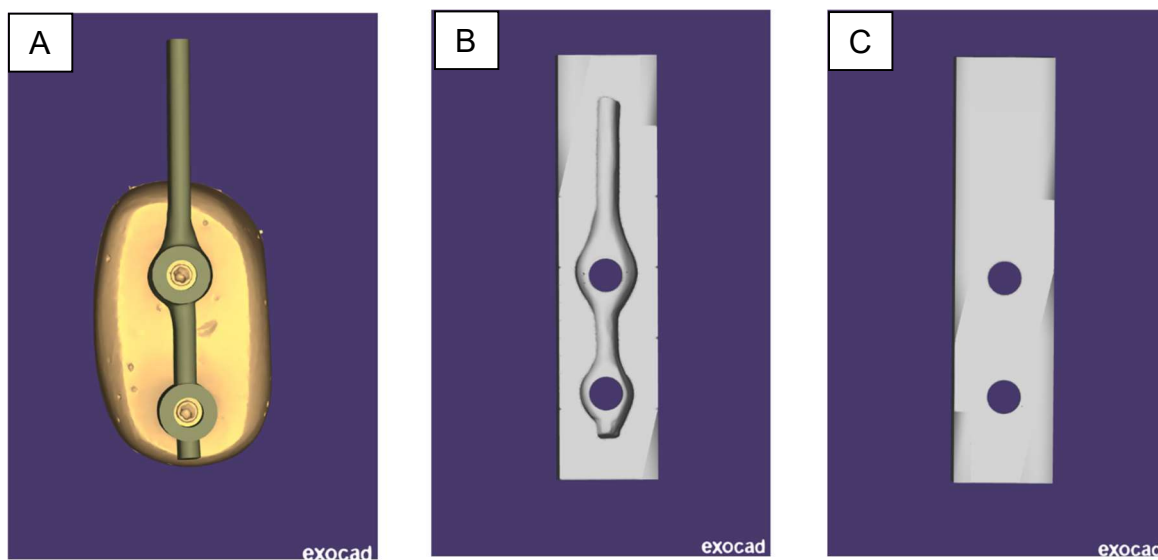


Figure 2- A Drawing in exocad of the metal bar that will be printed and then included and will go through the casting process B/C - Drawing of examples of resin bars.



Figure 3 metallic infrastructure cast and finished in nickel chrome, and printed resin bars that will be used as a mold to pour the study resins.

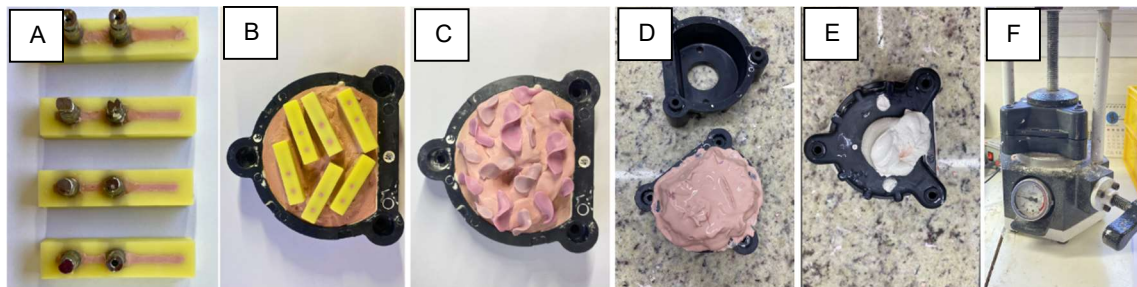


Figure 4 - Inclusion process: A- capture of analogues in the resin base; B- 1st stage of inclusion in a muffle with type IV stone plaster; C- Addition silicone walls and retentions; D- Plaster on the wall; E- Closing the muffle with dry plaster; F- Taking the muffle

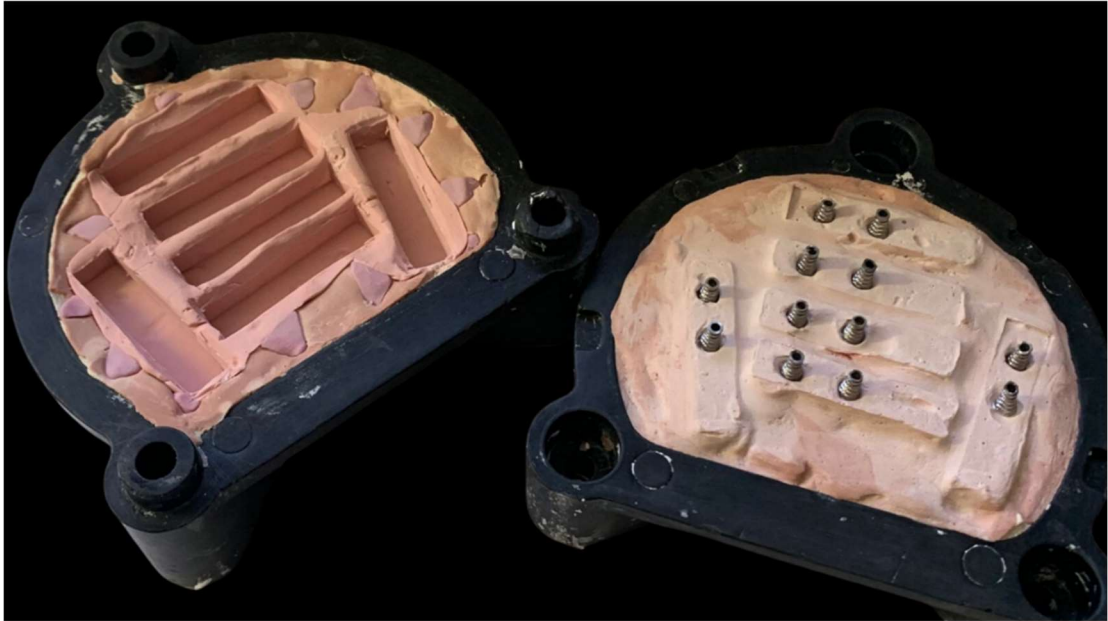


Figure 5 – RA and RD groups included in the muffle, after capturing the components and opening the muffle, ready to pour the resin

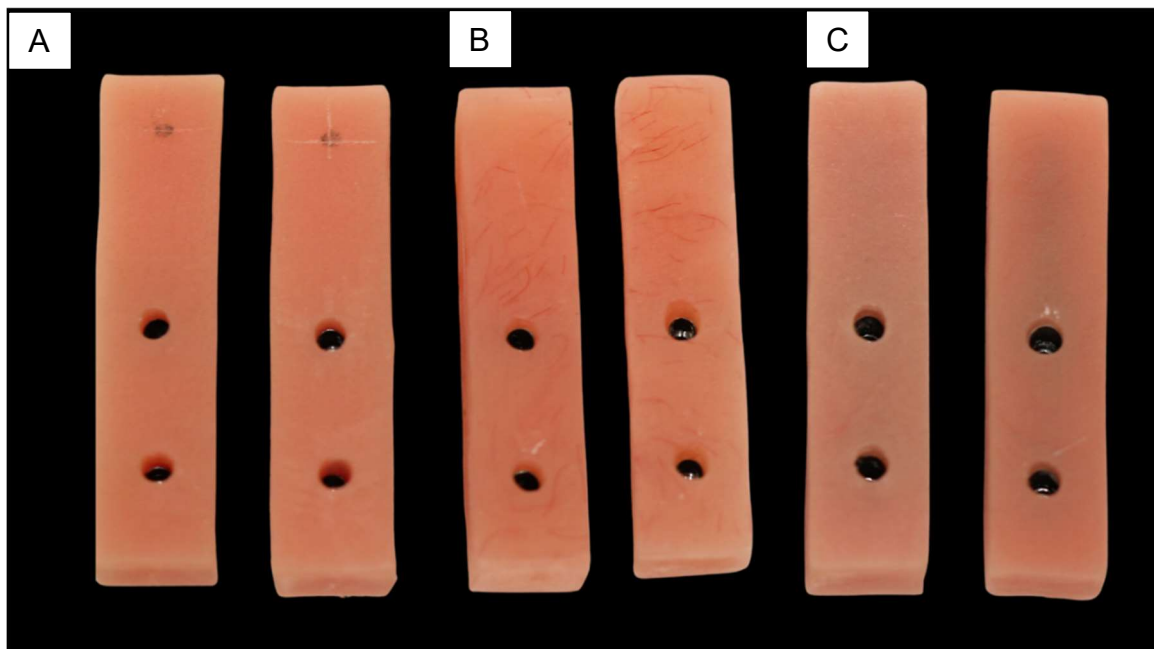


Figure 6 – Final aspect of all groups A - conventionally auto-polymerized resins (RA); B- High resistance Thermo-polymerized resin (RD); C-conventionally Thermo-polymerized denture resin (RT)

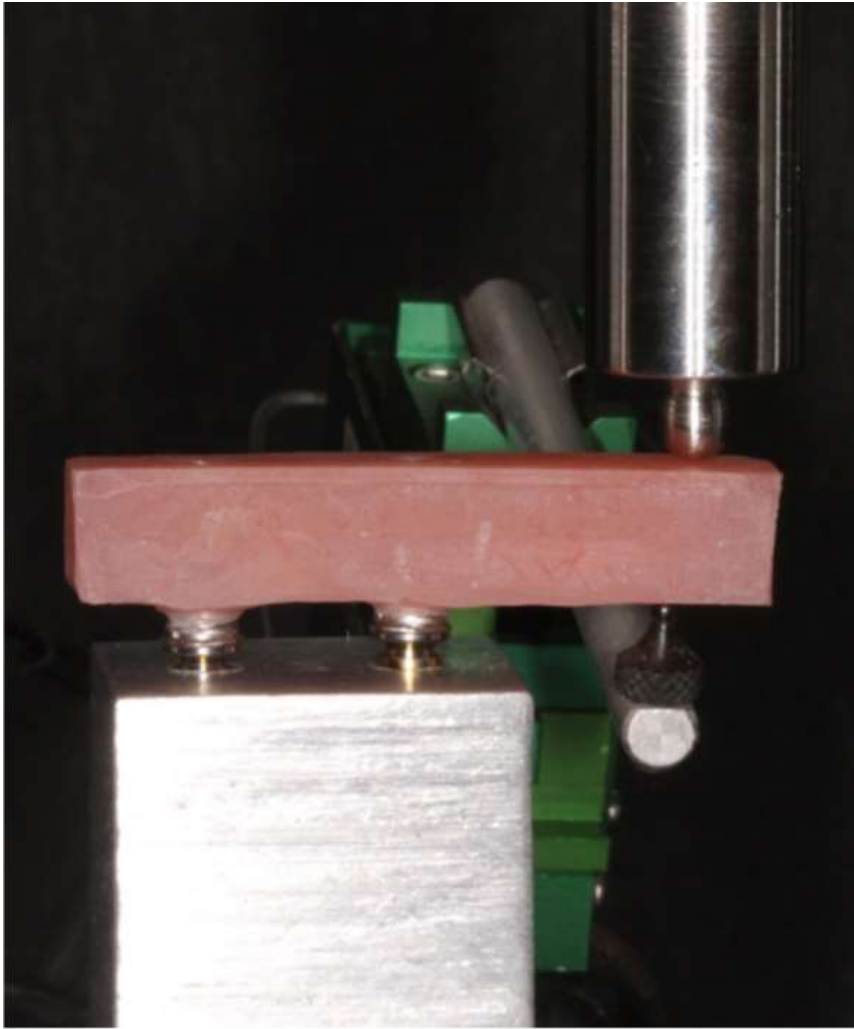


Figure 7- Specimens on the base, with the Instron tip and deflectometer positioned 5 mm from the end of the sample, ready to begin testing.

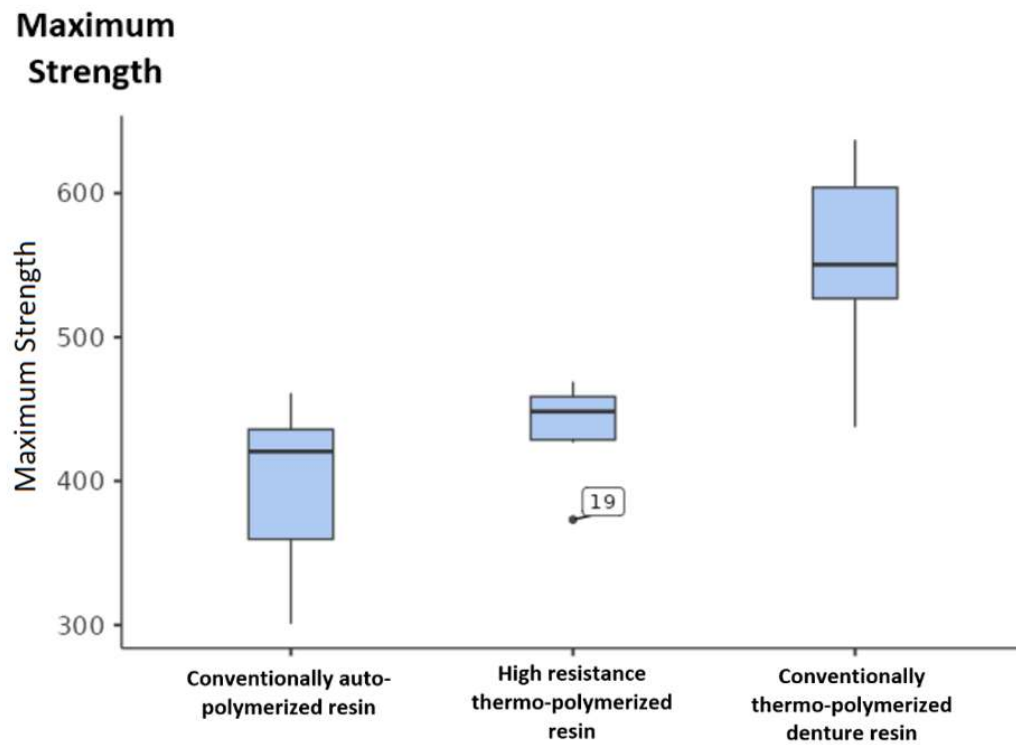


Figure 8- mean maximum strength of the groups was: RA: 396 N, RD: 440 N, RT: 553 N

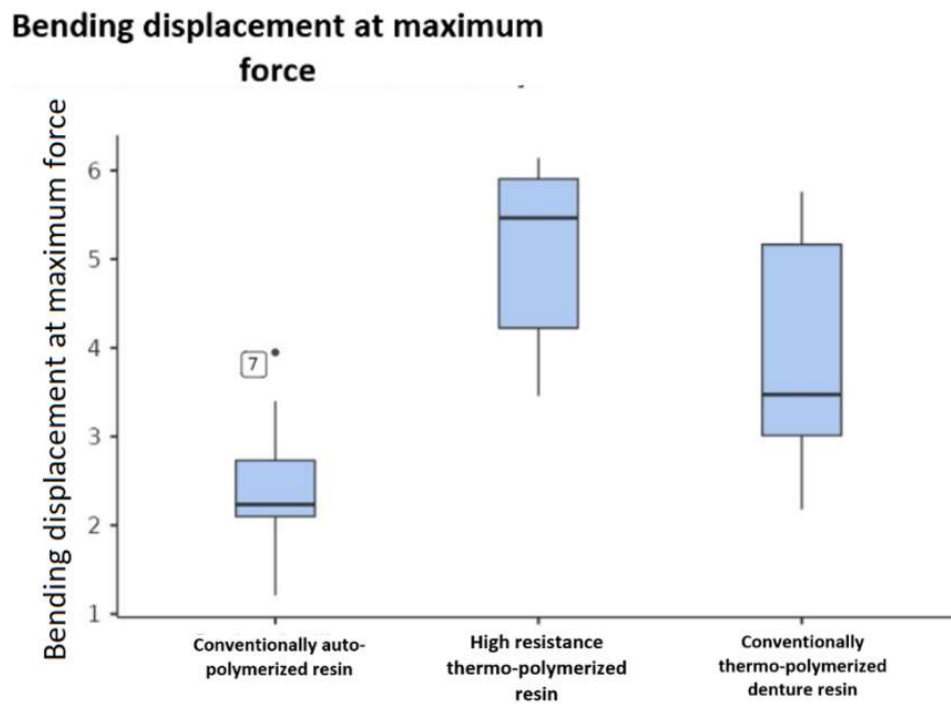


Figure 9 -Graph where we can observe the displacement of the samples at maximum force, we observe that the High resistance thermo-polymerized resin presents a greater displacement compared to the other two groups.

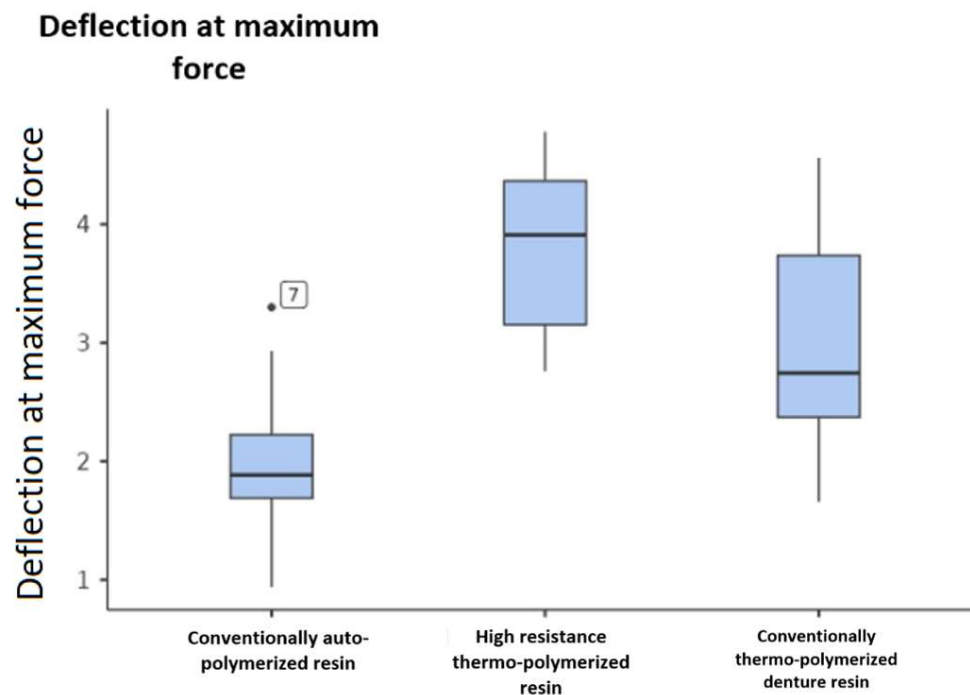


Figure 10- Graph showing the deflection of the 3 groups showing that the high-impact acrylic resin has a greater displacement compared to the other two resins, the DR has a significantly greater deformation before fracture occurs.



Figure 11- Example of how fractures of the resin samples looked after the tests A - conventionally self-polymerized resins (RA); B- High resistance Thermo-polymerized resin (RD); C-conventionally Thermo-polymerized denture resin (RT)

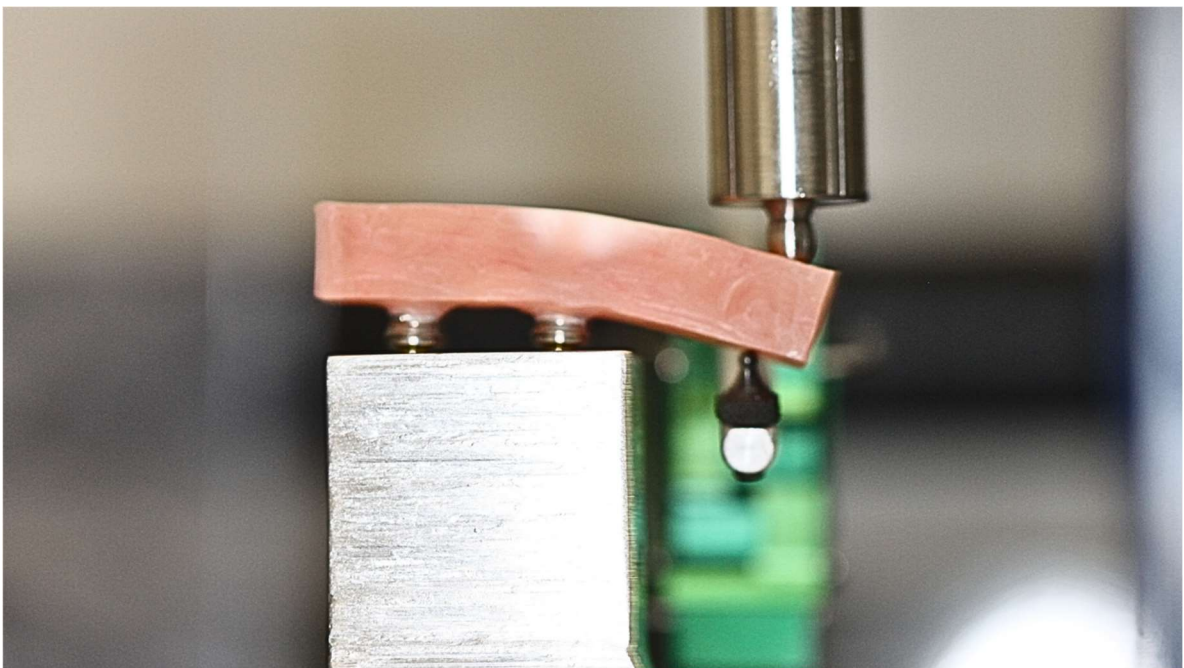


Figure 12- Sample of high-resistance resin close to the fracture, image shows how much it can deflect, and how it turns white in the region where the force is greatest

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