Universidade de Lisboa

Faculdade de Medicina Dentária

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Maria Manuel de Carvalho Nunes Teixeira Santos

Dissertação

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Dissertação orientada pelo

Professor Doutor Jaime Pereira Fontes de Almeida Portugal

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Aos meus pais,

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Abstract

Objective: The aim of the present study was to evaluate the effect of post-polymerization heat treatment on the flexural strength (FS) of two bis-acrylic resins.

Materials and Methods: Two commercially available autopolymerized bis-acrylic resins were tested: Structur 3 (S3), (VOCO GmbH, Cuxhaven, Germany) and Protemp 4 (P4), (3M ESPE, Minnesota, USA). A stainless-steel mold was used to fabricate the specimens with a dimension of 25x2x2 mm according to ISO 4049:2000 standards. A total of 50 specimens were fabricated using each material (N=100). After fabrication, specimens were randomly allocated to 10 experimental groups (n=10) and immediately subjected to the respective post-polymerization heat treatment used: no treatment, nt; conventional hairdryer 2200 W at a distance of 20 cm at a temperature of 60°C for 1 minute, hd1; microwave at 750 W for 1 minute, mw1; water bath at 60ºC for 1 minute, wb1; water bath at 60ºC for 5 minutes, wb5. Specimens were stored in a dry environment at room temperature (20±2ºC) until testing. Three-point bending test was performed at 30 minutes after initiating the mixing process. Additionally, a positive control group was made for each material in which the specimens were not submitted to any type of post-polymerization heat treatment and were tested at 24 hours after the beginning of the mix (S3-nt-24 and P4-nt-24). Data was submitted to ANOVA ($\alpha = 0,05$).

Results: All post-polymerization treatments significantly ($P<0.001$) increased the FS compared to the untreated group measured at 30 minutes for the two resins. The S3-wb5 group had statistically similar values ($P> 0.05$) to S3-nt-24. P4-hd1, P4-mw1 and P4-wb5 did not show significant differences ($P >0.05$) compared to P4-nt-24.

Conclusion: Post-polymerization heat treatments increased FS of the two resins tested. It is possible to obtain FS values at 30 minutes similar to those obtained at 24 hours with specific treatments.

Keywords: Bis-acryl; Flexural Strength; Heat Treatment; Mechanical Properties; Composite Resin; Post-polymerization.

Resumo

Introdução: As resinas bis-acrílicas surgiram no mercado nos anos 90 com o objetivo de colmatar as falhas das resinas de metacrilato. Estes materiais são semelhantes às resinas compostas sendo constituídos por monómeros multifuncionais de dimetacrilato e por cargas inorgânicas. As cargas inorgânicas são responsáveis por um aumento na resistência à abrasão, enquanto os monómeros de dimetacrilato permitem a formação de ligações cruzadas de alta densidade durante a polimerização, levando a uma maior resistência destes materiais. Hoje em dia, os compostos bis-acrílicos ganham relevância e popularidade porque, quando comparados com as resinas de metacrilato, possuem um odor mínimo, um sabor insignificante, uma reduzida contração de polimerização e uma menor toxicidade. Além disso, estes materiais apresentam uma menor reação exotérmica, mínima irritação pulpar, uma maior resistência à abrasão, melhor adaptação marginal e uma estabilidade cromática controversa. Outra vantagem é que oferecem um conveniente sistema de entrega em seringas de automistura que facilitam a manipulação e permitem a aquisição de uma mistura precisa e consistente com uma menor incorporação de ar. No entanto, uma desvantagem apontada às resinas bis-acrílicas, é a sua fraca resistência inicial. Na verdade, durante as primeiras horas após a fabricação, a sua rigidez e resistência são comparativamente baixas podendo conduzir a fraturas. Contudo, foi demonstrado que a resistência do material aumenta em 24 horas após o início da manipulação. Tendo em consideração que uma fratura pode afetar negativamente o resultado do tratamento, implicar consultas adicionais e, consequentemente, envolver maiores custos, seria importante encontrar uma forma de alcançar valores de resistência inicial mais altos, permitindo que os pacientes saiam da clínica com uma restauração totalmente funcional e com menor risco de fratura. Alguns estudos referem que as resinas autopolimerizáveis apresentam menor resistência à fratura do que as resinas termopolimerizáveis. Essa baixa resistência é devida à elevada quantidade de monómero residual que funciona como plastificante afetando negativamente as propriedades físicas e mecânicas das resinas acrílicas. Diversos estudos demonstraram que o grau de conversão destas resinas pode ser melhorado com recurso a tratamentos térmicos pós-polimerização. No entanto, o efeito destes tratamentos na resistência à flexão das resinas bis-acrílicas encontra-se ainda pouco investigado na literatura.

Materiais e Métodos: Foram fabricadas um total de 50 amostras de cada resina bis-acrílica autopolimerizável testada (N=100): Structur 3 (S3), (VOCO GmbH, Cuxhaven, Alemanha) e Protemp 4 (P4), (3M ESPE, St. Paul Minnesota, EUA). Um molde de aço inoxidável foi utilizado para fabricar as amostras de cada resina com as dimensões padronizadas de 25 x 2 x 2 mm de acordo com as normas ISO 4049: 2000 (E). Cada material foi manipulado de acordo com as instruções do fabricante e inserido no molde sobre uma folha de acetato e uma placa de vidro. Seguidamente, colocou-se uma nova folha de acetato e uma segunda placa de vidro sobre o material e aplicou-se pressão digital de modo a deslocar o excesso de resina do molde. Todos os espécimes foram deixados a polimerizar sem perturbações durante 4 ou 5 minutos (Structur 3 e Protemp 4, respetivamente) de acordo com as instruções do fabricante. Após polimerização, os espécimes foram removidos do molde, cuidadosamente inspecionados e foi feita a remoção dos excessos com recurso a uma lâmina de bisturi. As dimensões das amostras foram verificadas com uma craveira digital (Fischer Darex, Le Chambon Feugerolles, France) com uma precisão de 0,01mm. Após confeção, os espécimes foram divididos aleatoriamente em 10 grupos experimentais (n=10) e imediatamente submetidos ao tratamento térmico pós-polimerização correspondente: secador convencional de 2200 W (Philips; SalonDry Control Secador HP8182/23 Países Baixos) a uma distância de 20 cm e temperatura de 60°C durante 1 minuto (hd1), micro-ondas (Samsung, GW73B, Coreia do Sul) a 750 W durante 1 minuto (mw1), banho de água (JP Selecta, Precisterm, Espanha) a 60°C durante 1 minuto (wb1), banho de água (JP Selecta, Precisterm, Espanha) a 60ºC durante 5 minutos (wb5). Após o tratamento, os espécimes foram armazenados a seco e à temperatura ambiente (20 ± 2ºC) até serem testados. Os espécimes dos grupos controlo (nt) foram armazenados à temperatura ambiente, desde a fabricação até o momento em que o teste de flexão foi realizado, e não foram submetidos a qualquer tipo de tratamento pós-polimerização. Os espécimes foram testados 30 minutos após o início da mistura. Adicionalmente, foi feito um grupo de controlo positivo para cada material, em que os espécimes não foram submetidos a qualquer tipo de tratamento térmico pós-polimerização e foram testados 24 horas após inicio da mistura (S3-nt-24 e P4-nt-24). Os testes de resistência à flexão foram efetuados com uma máquina de teste universal *Instron* (Instron Ltd., Bucks, 4502h3307, Inglaterra), com uma célula de carga de 1 kN e uma

velocidade de cruzamento de 0,75 mm/min. A carga no momento da fratura foi registrada em MegaPascal (MPa). A análise estatística foi realizada com recurso ao programa estatístico SPSS 25.0 (*SPSS Inc*., Chicago, EUA). Os dados obtidos foram analisados com ANOVA de 2 dimensões, seguindo-se ANOVA de 1 dimensão e teste *post-hoc* de Tukey para comparar os grupos experimentais de cada material ($\alpha = 0,05$). Foi ainda utilizada, ANOVA de 1 dimensão seguida por um teste *post-hoc* de Dunnett para comparar os valores de resistência à flexão de cada grupo experimental com o controlo de 24 horas ($\alpha = 0,05$).

Resultados: Os valores médios de resistência à flexão (RF) variaram entre 99,1 MPa para o grupo P4-nt e 252,4 MPa para o P4-mw1. A ANOVA de 2 dimensões mostrou que a resistência à flexão foi influenciada ($p < 0,001$) pelo tipo de material e tratamento pós-polimerização usado, e uma interação ($p < 0,001$) entre os fatores foi detetada. No geral, todos os tratamentos pós-polimerização aumentaram significativamente ($p < 0,001$) a resistência à flexão comparativamente ao grupo sem tratamento (nt) medido aos 30 minutos para as duas resinas. Para S3, o valor médio de resistência à flexão encontrado no grupo S3-wb5 foi significativamente ($p < 0,05$) maior do que os resultados observados com os demais tratamentos térmicos pós-polimerização. Não foram encontradas diferenças ($p > 0,05$) entre S3-hd1, S3-mw1 e S3-wb1. Para P4, o grupo P4-wb1 mostrou uma resistência à flexão média menor ($p < 0,05$) do que todos os outros grupos de tratamento térmico e o P4-mw1 apresentou valores médios mais elevados ($p < 0,05$) do que P4-hd1, mas nenhuma outra diferença foi encontrada ($p > 0,05$). Comparando os grupos não tratados, testados após 30 minuto vs. testados após 24 horas, um aumento significativo ($p < 0,001$) na resistência à flexão média foi observado para ambos os materiais. Em relação aos grupos cujos espécimes foram submetidos ao tratamento térmico, para o S3, apenas o S3-wb5 apresentou valores estatisticamente semelhantes ($p > 0,05$) ao S3-nt-24. Os demais grupos apresentaram uma resistência à flexão significativamente menor ($p < 0,05$) que S3-nt-24h. Para P4, os grupos P4-hd1, P4-mw1 e P4-wb5 não apresentaram diferenças significativas ($p > 0,05$) quando comparados ao P4-nt-24. Por outro lado, o grupo P4-wb1 apresentou uma RF significativamente ($p < 0,001$) menor que o P4-nt-24.

Conclusão: Todos os tratamentos térmicos pós-polimerização realizados aumentaram a resistência à flexão das duas resinas testadas. Foi possível obter valores de RF aos 30 minutos semelhantes aos obtidos às 24 horas com determinados tratamentos: banho

de água a 60°C durante 5 minutos para ambas as resinas; microondas a 750 W durante 1 minuto e tratamento térmico com secador de cabelo a 2200 W a 60°C durante 1 minuto para o Protemp 4.

Palavras-chave: Bis-acril; Resistência à flexão; Tratamento Térmico; Resina Composta; Pós-polimerização.

Introduction

Provisional restorations are used in prosthodontics while the definitive prothesis is being made. They are meant to be in function for a few weeks, after which, they should be replaced by the definitive protheses (Thompson *et al.,* 2014). Regardless of being used for a limited period of time, these restorations must comprise certain requirements to resist functional and non-functional loads. They should protect the pulp and the prepared teeth, maintain the adjacent and opposing teeth's relationships, enhance patient's aesthetics, allow normal masticatory functions, promote periodontal health, serve as an appraisal of the patient's oral health and allow diagnostic simulations where the limitation and treatment outcomes can be identified. In some situations, these types of restorations are used to reestablish or stabilizing teeth during maxillofacial, periodontal or implant procedures (Lee *et al.,* 2015; Thompson *et al.,* 2014; Mai *et al.* 2015; Michalakis *et al.,* 2006; Ogawa *et al.* 2000; Patras *et al. 2012;* Schwantz *et al.,* 2017). In these circumstances, a longer period of use may be required, and the deterioration of the provisional material can cause loss of occlusion and periodontal problems (Ogawa *et al.,* 2000). Consequently, the material used to fabricate these protheses should resist fracture, be durable, be biocompatible, have color stability and have a good marginal adaptation (Mai *et al.,* 2015). Several materials can be used but none possess all the requirements (Gratton *et al.,* 2004; Thompson *et al.,* 2014; Young *et al.,* 2001).

The most frequently used materials for fabrication of provisional restorations are autopolymerizing acrylic resins, particularly, polymethyl methacrylate (PMMA). Other materials that can be used are polyethyl methacrylate (PEMA), polyvinyl methacrylate, bis-acryl composite resins, and light-cured urethane dimethacrylates (Mai *et al.,* 2015; Ogawa *et al.,* 2000; Patras *et al., 2012;* Shim *et al.,* 2015).

The methacrylate resins were introduced in the middle of the XX century and have been used until today. However, they present a few disadvantages such as color instability, high polymerization shrinkage, low durability, unpleasant odor, high exothermic reaction and mucosa irritation associated with the monomer (Burns *et al.,* 2003; Lee *et al.,* 2015; Mai *et al.,* 2015; Schwantz *et al.,* 2017*;* Shim *et al.,* 2015).

Bis-acrylic materials were introduced to the dental market in the 1990s with the aim to overcome the disadvantages of the methacrylate resins (Schwantz *et al.,* 2017; Singh *et al.,* 2016). These materials are similar to composite resins once they are composed by multifunctional dimethacrylate monomers and inorganic fillers. The inorganic fillers are responsible for an increase in abrasion resistance while the dimethacrylate monomers allow high density crosslinks to form during the polymerization leading to a higher strength of this material (Burns *et al.,* 2003; Fleisch L *et al.*, 1984; Gujjiari AK *et al*., 2013; Kerby *et al.,* 2013; Peñate *et al.,* 2015; Singh *et al.,* 2016).

Nowadays, bis-acryl composites have gained relevance and popularity because, when compared to methacrylate resins, they have an insignificant taste, negligible odor, reduced polymerization shrinkage and fewer toxicity. In addition, these materials have a lower exothermic reaction, minimal pulpal irritation, superior resistance to abrasion, better marginal adaptation but a controversial color stability (Burns *et al.,* 2003; Gratton *et al*., 2004; Lee *et al.,* 2015; Mai *et al.,* 2015; Singh *et al*., 2016; Schwantz *et al.,* 2017*;* Shim *et al.,* 2015). Another advantage is that they offer a convenient automix delivery system which facilitates handling and provides a proper and consistent mix with less air incorporation (Gratton *et al.,* 2004; Schwantz *et al.,* 2017). For single-unit restorations it has many desirable characteristics but the higher cost, brittleness and difficulty to repair makes it a less favorable material for multi-unit long-term provisional protheses. Therefore, for those multi-unit restorations, PMMA materials remain the material of choice (Gratton *et al.,* 2004).

A disadvantage of bis-acrylic resins is their poor initial resistance. Within the first hours after fabrication, its stiffness and strength are comparatively low and fractures may occur. However, it was shown that the material resistance increases in 24 hours after the beginning of the manipulation (Kerby *et al.,* 2013). Bearing in mind that a fracture may negatively affect the treatment outcome and also result in additional appointments and, consequently, more costs, it would be important, to find a way to obtain higher initial resistance values, allowing patients to leave the clinic with a fully functional restoration with lower fracture risk.

Some studies report that autopolymerized resins have lower fracture resistance when compared to thermopolymerized resins (Takahashi *et al.*, 2008; Thompson *et al.*, 2014; SEO e*t al. 2007;* Vergani *et al.*,2005). This lower fracture resistance is due to the high amount of residual monomer which acts as a plasticizer and negatively affects the mechanical and physical properties of the acrylic resins (Durkan *et al.*, 2011; SEO *et al.* 2007; Urban *et al.* 2007; *Urban et al.* 2009). Additionally, the release of residual monomers can cause allergic responses, hypersensitivity, inflammation or ulceration of the oral mucosa (Bural *et al.*, 2011; SEO *et al.*, 2007; Vergani *at al.*, 2005).

Several studies have demonstrated that the degree of conversion of residual monomers in polymers can be improved with post-polymerization heat treatments. The use of immersion in hot water and microwave irradiation have been reported as effective heat treatments in reducing residual monomer content of autopolymerized resins (Bural *et al.*, 2011; Durkan *et al.*, 2011; Ogawa *et al.*, 2000; SEO *et al., 2007;* Takahashi *et al.*, 2008; Thompson *et al.*, 2014; Urban *at al.*, 2009; Vergani *at al.*, 2005).

Today there is a huge variety of restorative materials available and it is, therefore, more difficult to select the most suitable one. For this reason, it is imperative that clinicians make a weighted and reasoned decision, taking into consideration the mechanical and physical properties of the materials given that the selection of the appropriate one for each case can influence the success of the overall treatment.

Unfortunately, there is not a material that meets all the desirable characteristics for the fabrication of temporary restorations (Gratton *et al.*, 2004; Haselton *et al.*, 2002). For this reason, it is relevant to investigate and develop methods to improve the properties of the ones that are available (Gratton *et al.*, 2004). In this sense, there was the desire to develop a simple protocol that could be performed with easily accessible clinic materials and in the time available during the appointment in order to help the clinicians in improving their results.

Bis-acryl is a material with several advantages, growing in clinical practice, however, there is little information available in the literature on the effect of post-polymerization heat treatment on its mechanical properties (Thompson *et al.*, 2014).

Objectives

The aim of the present study was to evaluate the effect of post-polymerization heat treatment on the flexural strength of two bis-acrylic resins according to the null hypothesis:

1) the flexural strength is not influenced by post-polymerization heat treatment;

2) the material does not influence the flexural strength;

3) there are no differences between the flexural strength of the specimens tested at 30 minutes and 24 hours after the beginning of the mix.

Materials and Methods

1. Specimen preparation

Two commercially available autopolymerized bis-acrylic resins were tested: Structur 3 (S3), shade A3 (Batch No.1807226, ref. 2505, expiring date 2020-02, VOCO GmbH, Cuxhaven, Germany) and Protemp 4 (P4), shade A3 (Batch No.628352, ref. 70201132621, expiring date 2018-05, 3M ESPE, St. Paul Minnesota, USA) (Table 1 and Figure 1).

Table 1: Characteristics of the bis-acrylic resins used.

Material	Abbreviation	Batch No./Manufacturer	Composition*
Structur 3	S3	1807226/ VOCO GmbH, Cuxhaven, Germany	**Catalyst** (Urethanedimethacrylate, Bis GMA, benzoyl peroxyde); **Base** (Urethanedimethacrylate)
Protemp 4	P4	628352/ 3M ESPE, St. Paul Minnesota, USA	**Catalyst** (2,2'-[(1-methylethylidene) bis (4,1- phenyleneoxy)] bisethydiacetate, benzyl-phenyl -barbituric acid, silane treated silica, Tert-butyl 3,5,5-trimethylperoxyhexanoate); **Base** (Dimethacrylate (bisema6), silane treated amorphous silica, reaction products of 1,6- diisocyanatohexane with 2-[(2- methacryloyl)ethyl]6-hydroxyhexanoate and 2-hydroxyethyl methacrylate (desma), silane treated silica)

**According to the information provided by the manufacturer.*

Figure 1: Bis-acrylic resins. A- Bis-acryl Structur 3. B - Bis-acryl Protemp 4.

A stainless-steel mold was used to fabricated bis-acrylic resin specimens with a dimension of 25 x 2 x 2 mm according to ISO 4049:2000 standards (Figure 2). Each resin material was manipulated according to the manufacturer's instructions and inserted into the mold placed onto an acetate sheet and a glass slab. A second acetate sheet and glass slab were placed over the material and digital pressure was applied to displace excess material from the mold. All specimens were allowed to polymerize undisturbed for 4 minutes (Stuctur 3) or 5 minutes (Protemp 4) according to the manufacturer's instructions. After the polymerization process was completed, the specimens were removed from the mold, carefully inspected and excess was removed with a scalpel. All samples that showed pores or irregularities were discarded and replaced. The specimens were cleaned with a cotton ball soaked in alcohol. The cotton ball was rugged on both surfaces to remove the surface layer of material which could have had its polymerization inhibited due to contact with oxygen, according to the instructions of the respective manufacturers. The accuracy of the dimensions was verified with a digital caliper (Fischer Darex, Le Chambon Feugerolles, France) with an accuracy of 0.01 mm. A total of 50 parallelepiped specimens were fabricated with each material (N=100) (Figure 3).

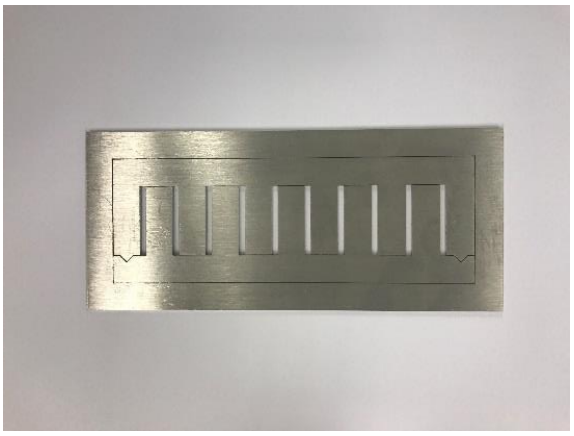

Figure 2: Stainless-steal mold used to fabricate the specimens.

Figure 3: Specimen representative of the sample.

After fabrication, specimens were randomly divided into ten experimental groups (n=10) and post-polymerization heat treatments were immediately performed. All procedures were carried out in a standardized manner by the same operator (Table 2).

2. Post-polymerization heat treatment

Four different types of post-polymerization heat treatments were tested: heat generated by a conventional hairdryer 2200 W (hd1; Philips, SalonDry Control Hairdryer HP8182/23, Netherlands) at a distance of 20 cm and temperature of 60°C for 1 minute; microwave at 750 W (mw1; Samsung, GW73B, South Korea) for 1 minute; water bath (wb1; J.P. Selecta, Precisterm, Spain) at 60°C for 1 minute; and water bath (wb5; J.P. Selecta, Precisterm, Spain) at 60°C for 5 minutes. After post-polymerization treatments, specimens were stored in a dry environment at room temperature (20±2ºC) until testing. The specimens used for the control groups (nt) were stored at room temperature, since the fabrication to the moment that the flexural test was performed and were not submitted to any post-polymerization treatment. All specimens were tested 30 minutes after the beginning of the mix.

Table 2: Representative table of thermal treatments and corresponding experimental groups.

Material	Treatment	Experiemental group
Structur 3	Without treatment	S3-nt
	Hair dryer for 5 minutes	S3-hd1
	Microwave at 750W for 5 minutes	S3-mw1
	Water bath at 60ºC for 1 minute	S3-wb1
	Water bath at 60ºC for 5 minutes	S3-wb5
Protemp 4	Without treatment	P4-nt
	Hair dryer for 5 minutes	P4-hd1
	Microwave at 750W for 5 minutes	P4-mw1
	Water bath at 60 for 1 minute	P4-wb1
	Water bath at 60 for 5 minutes	P4-wb5

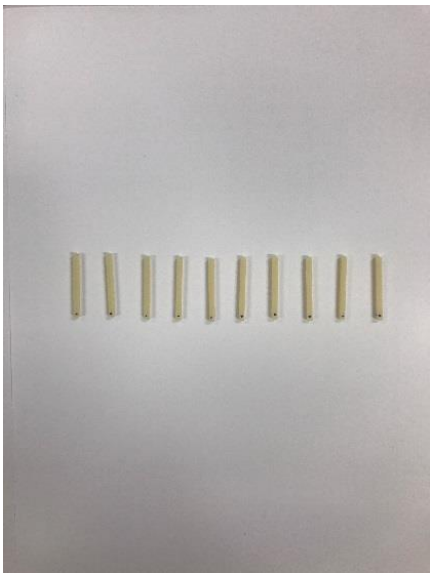

Figure 4: No-treatment group (nt).

Figure 5: Hairdryer post-polymerization group (hd1). Specimens subjected to post-polymerization heat treatment with a conventional hairdryer 2200 W at a distance of 20 cm at a temperature of 60°C for 1 minute. The hairdryer distance was verified with a mark set at 20 centimeters and the samples were stabilized with tape on one end. The temperature was monitored using a thermometer.

Figure 6: Microwave post-polymerization group (mw1). Specimens were directly placed in a microwave at 750 W for 1 minute;

Figure 7: Water bath post-polymerization group (wb1¸wb5). The specimens were submerged in a water bath programmed at 60°C for 1 or 5 minutes according to the experimental group. The temperature was verified using a thermometer. After 1 or 5 minutes, the samples were carefully removed from the water bath and dried with absorbent paper.

Additionally, a positive control group was made for each material in which the specimens were not subjected to any type of post-polymerization heat treatment and were tested at 24 hours after the beginning of the mix (S3-nt-24 and P4-nt-24) (Figure 4).

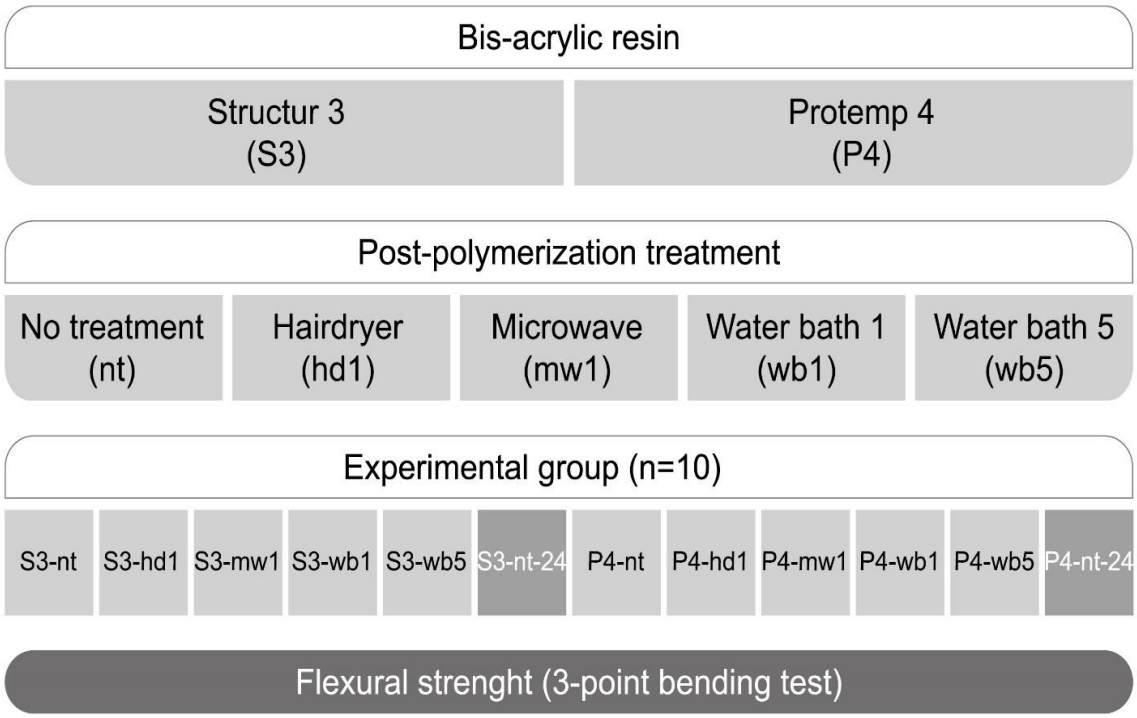

Figure 8: Experimental design (n=10). S3, Structur 3; P4, Protemp 4; nt, no post-polymerization treatment; hd1, conventional hairdryer 2200 W at a distance of 20 cm at a temperature of 60°C for 1 minute; mw1, microwave at 750 W for 1 minute; wb1, water bath at 60ºC for 1 minute; wb5, water bath at 60ºC for 5 minutes; 24, measured at 24 hours after beginning of the mix.

3. Flexural strength

A 3-point bending test was performed to assess flexural strength (FS) sing a universal Instron mechanical testing machine (Instron Ltd., Bucks,4502h3307, England), with a 1 kN load cell, at a cross-head speed of 0.75 mm/min. Two rods were positioned at a distance of 20 mm between their centers, and a third rod was placed between and parallel to the preceding

ones, so that the combination of the three stems provided a 3-point support for the specimen. The load at the moment of the fracture was recorded in Megapascal (MPa). Flexural strength was determined by using the following equation: $\frac{3Fl}{2bh^2}$, where F is the maximum load before fracture (N), l is the distance in millimeters between the supports (with an accuracy of ± 0.01 mm), b is the width of the specimen measured just before the tests (mm) and h is the thickness of the specimen measured just before the tests (mm).

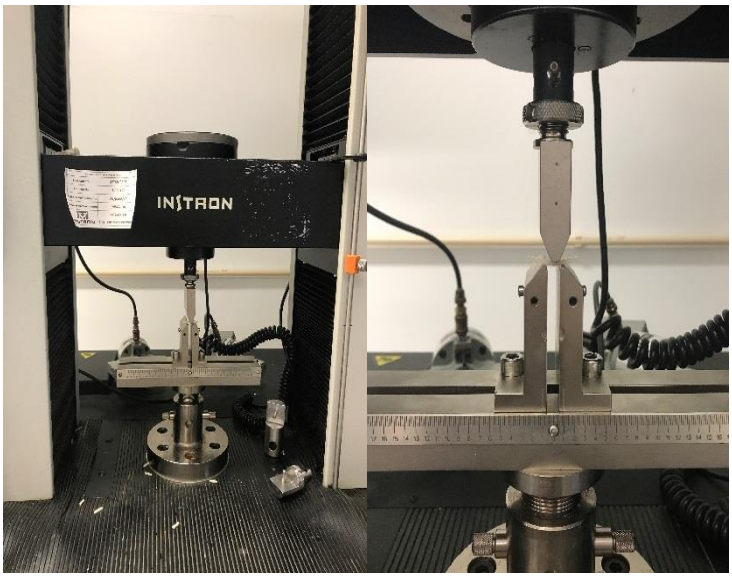

Figure 9: Measuring the FS Instron mechanical testing machine.

Statistical analysis was performed using the statistical program SPSS 25.0 (SPSS Inc., Chicago, USA). The normality of the sample distribution and the homogeneity of the variance were verified with Shapiro-Wilk and Levene tests, respectively ($p>0.05$). Data were submitted to a 2-way ANOVA, followed by 1-way ANOVA and Tukey post-hoc tests to compare experimental groups of each material ($\alpha=0.05$). Additionally, 1-way ANOVA followed by a Dunnett post-hoc tests were performed to compare each experimental group with control 24 hours flexural strength ($\alpha=0.05$).

Results

The mean flexural strength ranged between 99.1 MPa for P4-nt group and 252.4 MPa for P4-mw1.

Table 3: Descriptive statistic of the Flexural Strength of the 12 experimental groups.

Material	Treatment	Experimental Group	Flexural Strength (MPa) Mean (SD)
S3	No treatment	S3-nt	125.7 (18.43)
	Hairdryer	S3-hd1	162.4 (20.73)
	Microwave	S3-mw1	168.4 (24.12)
	Water bath for 1 minute	S3-wb1	173.2 (22.55)
	Water bath for 5 minutes	S3-wb5	203.3 (16.55)
	No treatment 24 hours	S3-nt-24	205.5 (13.37)
P4	No treatment	P4-nt	99.1 (26.30)
	Hairdryer	P4-hd1	215.8 (17.60)
	Microwave	P4-mw1	252.4 (33.46)
	Water bath for 1 minute	P4-wb1	167.3 (27.99)
	Water bath for 5 minutes	P4-wb5	227.4 (32.01)
	No treatment 24 hours	P4-nt-24	234.0 (20.03)

Mean and standard deviation according with the 12 experimental groups (N=120). S3, Structur 3; P4, Protemp 4; nt, no post-polymerization treatment; hd1, conventional hairdryer 2200 W at a distance of 20 cm at a temperature of 60°C for 1 minute; mw1, microwave at 750 W for 1 minute; wb1, water bath at 60ºC for 1 minute; wb5, water bath at 60ºC for 5 minutes; nt-24, no post-polymerization treatment measured at 24 hours.

Two-way ANOVA showed that FS was statistically influenced ($p<0.001$) by the type of material and post-polymerization treatment used, and a significant interaction ($p<0.001$) between factors were detected.

In general, all post-polymerization treatments significantly ($p<0.05$) increased the FS compared to the untreated group measured at 30 minutes for the two resins (Figure 10).

For S3, the mean value of flexural strength found in group S3-wb5 was significantly

($p<0.05$) higher than the results observed with the other post-polymerization heat treatments. No differences ($p>0.05$) were found between S3-hd1, S3-mw1 and S3-wb1 (Figure 10).

For P4, the P4-wb1 specimens showed a lower ($p<0.05$) mean flexural strength than all the other heat treatment groups and the P4-mw1 yielded higher ($p<0.05$) mean values than P4-hd1, but no other differences were found ($p>0.05$) (Figure 10).

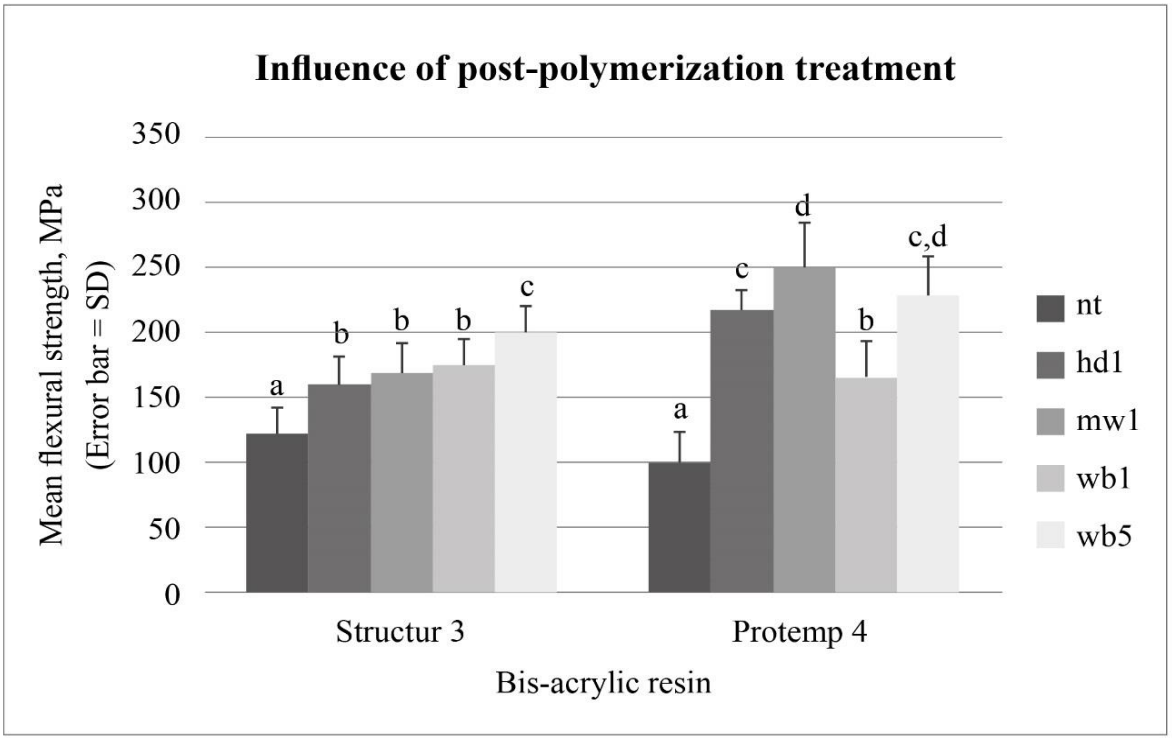

Figure 10: Influence of post-polymerization treatment on the flexural strength for the two bis-acrylic resins tested. SD, standard deviation; MPa, megapascal; nt, no post-polymerization treatment; hd1, conventional hairdryer 2200 W at a distance of 20 cm at a temperature of 60°C for 1 minute; mw1, microwave at 750 W for 1 minute; wb1, water bath at 60ºC for 1 minute; wb5, water bath at 60ºC for 5 minutes; For each study condition (combination of material and post-polymerization treatment) mean flexural strength values with the same superscript letters were not significantly different ($p>0.05$).

Comparing the untreated groups, tested after 30 minutes *vs*. tested after 24 hours, a significant ($p<0.001$) increase in mean flexural strength was observed for both materials

(Table 4). Regarding to the groups which specimens were submitted to heat treatment, for the S3, only the S3-wb5 had statistically similar values ($p>0.05$) to S3-nt-24. The remaining groups showed significant lower ($p<0.05$) FS than S3-nt-24h (Table 4). For P4, the groups P4-hd1, P4-mw1 and P4-wb5 did not present significant differences ($p>0.05$) when compared to the P4-nt-24. On the other hand, the P4-wb1 group showed a significant ($p<0.001$) lower FS than P4-nt-24 (Table 4).

Table 4: Dunnet Multiple Comparation tests comparing mean flexural strength between 24 hours control and experimental groups.

Experimental Group (I)	Control Group (J)	Mean Difference (I-J)	Std. Error	Sig. *
S3-nt	S3-nt-24	-79.74	8.78	p<0.001
S3-hd1		-43.09	8.78	p<0.001
S3-mw1		-37.09	8.78	p<0.001
S3-wb1		-32.27	8.78	p<0.001
S3-wb5		-2.23	8.78	0.999
P4-nt	P4-nt-24	-134.86	12.01	p<0.001
P4-hd1		-18.16	12.01	0.422
P4-mw1		18.39	12.01	0.410
P4-wb1		-66.73	12.01	p<0.001
P4-wb5		-6.63	12.01	0.974

*Std. Error, standard error; Sig., significance level; S3, Structur 3; P4, Protemp 4; nt, no post-polymerization treatment; hd1, conventional hairdryer 2200 W at a distance of 20 cm at a temperature of 60°C for 1 minute; mw1, microwave at 750 W for 1 minute; wb1, water bath at 60ºC for 1 minute; wb5, water bath at 60ºC for 5 minutes; nt-24, no post-polymerization treatment measured at 24 hours. *p<0.001 indicates statistically significant differences.*

Discussion

Flexural strength, also known as fracture strength or bending strength, is a materials ability to resist deformation under load. It represents the highest stress experienced within the material at its moment of rupture (Mai *et al,* 2015). FS is a mechanical property that has been widely used to evaluate the strength and stiffness of provisional materials. The flexural test includes tensile and compressive stress and is especially important when an interim restauration must remain for an extended period of time in function (Anusavice *et al.,* 2013; Kerby *et al.,* 2013, Poonacha *et al.,* 2013). In this study, a three-point bending test was performed in order to assess FS. This test determines not only the strength but also the expected distortion of the material indicated (Singh *et al.,* 2016).

Provisional restorations are often fitted and cemented shortly after fabrication (10 to 30 minutes after setting), exposing them to occlusal stress almost immediately. Because of this, mechanical stability in this early stage, is essential to prevent failure of the provisional. However, previous studies have shown that initial mechanical strength and fracture as well as toughness of bis-acrylic resins are much lower than after 24 hours (Knobloch *et al.,* 2009; Balkenhol *et al*., 2008; Kerby *et al,* 2013). Poonacha *et al.,*2013, observed that FS of bis-acrylic resins significantly increased after being stored for 24 hours and did not show relevant changes after 7 days of storage in artificial saliva. In the present study, similar results were found with an increase of FS from 30 minutes to 24 hours, for both resins. Therefore, the third null hypothesis was rejected.

For bis-acrylic resins very little information about the effect of post-polymerization heat treatment in the properties of the material is available so far (Thompson *et al.,* 2014; Shim *et al.,* 2015). However, heat treatments have been widely investigated and tested for other provisional materials and have showed to be advantageous in the enhancement of the mechanical properties (Burns *et al.,* 2003; Ogawa *et al,* 2000). The purpose of this study was to validate if post-polymerization heat treatments improve, or not, the initial FS (30 minutes after beginning of the mix) of two different bis-acrylic based resin materials in order to achieve a more desirable clinical performance.

The results obtained show that the FS of the two bis-acrylic resins tested was influenced by post-polymerization heat treatment. Therefore, the first null hypothesis was rejected. In general, de addition of heat increased the FS values when compared with no treatment (nt) groups. These results might be explained by an increase of the degree of conversion (Mai *et al*, 2015).

The type of material had significant effect on FS, therefore the second null hypothesis was also rejected. The differences in the physical behavior of the two types of bis-acryl based materials tested could be explained by the differences in the material's composition (Mai *et al.*, 2015; Poonacha *et al.*, 2013; Schawantz *et al.*, 2017).

For S3, post-polymerization heat treatment wb5 was the only one with similar FS values as the ones achieved at 24 hours. The remaining groups, while they showed values of FS superior to the group without treatment, these were not enough to reach the maximum resistance obtained at 24 hours.

For P4, all the post-polymerization heat treatments except wb1 significantly increased the FS to similar values as those verified at 24 hours. The wb1 showed improved FS when compared with no treatment groups but that was not sufficient to reach the maximum resistance.

In this study a gain in FS was found when the samples were placed in a water bath at 60ºC for 1 or 5 minutes. One possible explanation is that placement in water may have extended the polymerization reaction of the resins tested (Thompson *et al.*, 2014; Takahashi *et al.*, 2009). Heat activates the reaction between monomers and polymers, leading to a more complete polymerization (Ogawa *et al.*, 2000). Another possibility is the likely reduction of the residual monomer content by the dissolution of the monomer molecules in the water. This diffusion is a temperature dependent process; therefore, a heightened temperature enhances the dissemination (Urban *et al.*, 2009). Additionally, the presence of free radicals in the polymer chain may favor the continuation of the polymerization process (SEO *et al.*, 2007) and at higher temperatures, monomer molecules may spread faster to these active sites reducing the levels of residual monomer (Covey *et al.*, 1992; Urban *et al.*, 2007). These hypotheses are supported by earlier studies which found that after immersion in hot water the

residual monomer content decreased significantly for all acrylic resins tested (Urban *et al.*, 2007). It is important to note that the temperature of the water bath used in this study was 60ºC and that benzoyl peroxide is activated at temperatures between 50ºC and 60ºC (Sakaguchi *et al.*, 2012). Even though, in this study, the specimens were only immersed in the water bath for 1 or 5 minutes the temperature used most likely enhanced the before mentioned mechanisms.

For microwave post-polymerization heat treatment, the FS was also improved when compared with the nt group for both resins tested. These findings are supported by previous investigations that tested the effect of microwave irradiation on autopolymerizing acrylic resins (Blagojevic *et al.*,1999; Patil *et al.*, 2009; Vergani *et al.*, 2005). Microwave postpolymerization reduced residual monomer, augmented the impact strength and improved the glass transition temperature (Tg) (Blagojevic *et al.*, 1999). This may be explained by probably extension of the polymerization reaction produced by the heat generated during microwave irradiation resulting in the reduction of the residual monomer content (Patil *et al.*, 2009; Seo *et al.*, 2007; Takahashi *et al.*, 2008). A monomer volatilization was also suggested for explaining the decrease in residual monomer and consequentially the improvement of mechanical properties (Bagis *et al.*, 2000). Given that in the present study the specimens were placed in the microwave in a dry state, the diffusion mechanism that was mentioned to the water bath was not involved in the increasing of FS. Placing the specimens in water might lead to plasticization of the resin, making it more flexible and resilient (Vergani *et al.*, 2005), hence dry conditions were preferred. Although the two bis-acrylic resins tested showed better results of FS after heat treatment with microwave at 750 W for 1 minute, the results between the materials were different.

Post-polymerization heat treatment with hair dryer heating also proved to be an effective method to improve FS. There is no existing information on the use of the hair dryer in the properties of provisional dental materials. However, the heating principle is the same, thus the improvement observed in the FS may be related to an increase in the degree of conversion as mentioned above.

One limitation of the present study is that other treatment times have not been tested,

however, the purpose of this study was to test an executable treatment in a clinical setting taking into account the time limitation of a normal dental practice visit. Further studies are needed to understand if the times tested are the most effective. Likewise, other temperatures were also not tested, and further studies are necessary to compare the results and to determine the optimum temperature for the post-polymerization heat treatment.

It's particularly relevant that the provisional material has adequate strength soon after the initial polymerization to prevent failure of the restauration (Balkenhal *et al.*, 2008; Kerby *et al.*, 2013). The results obtained show that it is possible to reach values of FS similar to those obtained at 24 hours, at 30 minutes also, by performing certain thermal treatments. Post-polymerization heat treatment in a 60°C water bath for 5 minutes seems to be a good option to increase the FS of both resins tested. In addition, microwave heat treatment at 750 W for 1 minute and post polymerization heat treatment with a hair dryer at 60°C for 1 minute also appears to be an effective method for increasing the FS of Protemp 4. However, although an increase of the FS was achieved through heat treatment on both bis-acryl resins tested, the effects on other properties are still unknown. Mai *et al.*, 2015, studied the influence of heat treatment during polymerization on the physical properties of provisional crowns and observed that flexural strength of the bis-acrylic resins tested cured at 60ºC increased but that there was also an increase in surface roughness and marginal discrepancy. These authors evaluated the effect of the heat treatment made during the polymerization while in the present study the heat treatment was done post-polymerization. Thus, it is still unknown whether the same conclusions about marginal discrepancy and roughness may be valid in this case. Then, in order to apply the results of this study to a clinical setting, more data regarding the effects of post-polymerization heat treatment on the other mechanical and optical properties of bis-acryl resins are needed.

Conclusion

Within the limitations of this study, the following conclusions were drawn:

1 - Post polymerization heat treatment significantly improves the flexural strength of both bis-acrylic resins tested, Structur 3 and Protemp 4.

2 - Flexural strength is influenced by bis-acrylic material.

3 - It’s possible to achieve similar flexural strength to 24 hours, at 30 minutes, by the following post-polymerization heat treatments: 60°C water bath for 5 minutes for both resins tested; microwave heat treatment at 750 W for 1 minute and post polymerization heat treatment with a hairdryer 2200 W at 60°C for 1 minute for Protemp 4.

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Appendices

Data from experimental group: S3-nt

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0375	37,5	140,6
2	0,0287	28,7	107,5
3	0,0413	41,3	154,8
4	0,0403	40,3	151
5	0,0336	33,6	126,1
6	0,0328	32,8	122,8
7	0,0271	27,1	101,6
8	0,0323	32,3	121
9	0,0337	33,7	126,4
10	0,0282	28,2	105,6

Data from experimental group: S3-hd1

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0367	36,7	137,4
2	0,0468	46,8	175,4
3	0,0497	49,7	186,5
4	0,0493	49,3	184,8
5	0,0413	41,3	154,8
6	0,0404	40,4	151,3
7	0,0491	49,1	184
8	0,0409	40,9	153,5
9	0,045	45	168,8
10	0,034	34	127,4

Data from experimental group: S3-mw1

N	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0502	50,2	188,1
2	0,054	54	202,5
3	0,0453	45,3	170,1
4	0,05	50	187,6
5	0,0568	56,8	213
6	0,0505	50,5	189,3
7	0,049	49	183,7
8	0,0479	47,9	179,8
9	0,0496	49,6	186
10	0,0515	51,5	195,6

Data from experimental group: S3-wb1

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0607	60,7	227,7
2	0,0624	62,4	233,9
3	0,0532	53,2	199,5
4	0,0507	50,7	190,3
5	0,0504	50,4	189,1
6	0,0529	52,9	198,3
7	0,0548	54,8	205,5
8	0,0562	56,2	210,9
9	0,0493	49,3	184,7
10	0,0514	51,4	192,6

Data from experimental group: S3-wb5

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0506	50,6	189,7
2	0,0532	53,2	199,5
3	0,0503	50,3	188,5
4	0,0531	53,1	199,3
5	0,0425	42,5	159,2
6	0,0447	44,7	167,7
7	0,0452	45,2	169,4
8	0,0397	39,7	148,7
9	0,0348	34,8	130,6
10	0,0479	47,9	179,5

Data from experimental group: S3-nt-24

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0515	51,5	193,1
2	0,0527	52,7	197,5
3	0,0497	49,7	186,5
4	0,0573	57,3	214,8
5	0,0499	49,9	187,1
6	0,06	60	224,9
7	0,0562	56,2	210,9
8	0,056	56	210,1
9	0,0572	57,2	214,5
10	0,0574	57,4	215,4

Data from experimental group: P4-nt

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0259	25,9	96,97
2	0,0418	41,8	156,9
3	0,0193	19,3	72,52
4	0,0233	23,3	87,52
5	0,035	35	131,4
6	0,0271	27,1	101,5
7	0,0193	19,3	72,3
8	0,0224	22,4	84,15
9	0,0251	25,1	94,05
10	0,0251	25,1	94,09

Data from experimental group: P4-hd1

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0658	65,8	246,9
2	0,0513	51,3	192,3
3	0,0562	56,2	210,8
4	0,059	59	221,3
5	0,0547	54,7	205,2
6	0,0599	59,9	224,8
7	0,062	62	232,6
8	0,0567	56,7	212,7
9	0,0506	50,6	189,6
10	0,0592	59,2	222,2

Data from experimental group: P4-mw1

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0736	73,6	275,9
2	0,0688	68,8	257,9
3	0,0522	52,2	195,8
4	0,0554	55,4	207,9
5	0,0809	80,9	303,5
6	0,0753	75,3	282,3
7	0,0659	65,9	247,3
8	0,0617	61,7	231,3
9	0,067	67	251,3
10	0,0722	72,2	270,7

Data from experimental group: P4-wb1

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0498	49,8	186,8
2	0,0566	56,6	212,2
3	0,0559	55,9	209,7
4	0,064	64	239,8
5	0,056	56	209,8
6	0,0497	49,7	186,6
7	0,0635	63,5	237,9
8	0,0728	72,8	272,9
9	0,064	64	240
10	0,0741	74,1	278

Data from experimental group: P4-wb5

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0301	30,1	112,8
2	0,0378	37,8	141,9
3	0,04	40	149,9
4	0,0452	45,2	169,5
5	0,0561	56,1	210,5
6	0,0457	45,7	171,3
7	0,0504	50,4	189
8	0,0419	41,9	157,1
9	0,0486	48,6	182,2
10	0,0503	50,3	188,5

Data from experimental group: P4-nt-24

n	Load (kN)	Load (N)	Flexural Strength (MPa)
1	0,0666	66,6	249,7
2	0,0589	58,9	220,8
3	0,0688	68,8	258,1
4	0,068	68	255,1
5	0,0607	60,7	227,5
6	0,0644	64,4	241,6
7	0,0638	63,8	239,2
8	0,0543	54,3	203,7
9	0,0538	53,8	201,7
10	0,0647	64,7	242,6

Instructions for use (Structur®3)

VOCO

USA

CE 0482

Structur® 3

Carefully read instructions prior to use

Product description:
Structur 3 is a cold-polymerizing paste-paste system based on multifunctional methacrylic acid esters for the fabrication of temporary restorations.

Shades:
Structur 3 in the cartridge: A1, A2, A3, A3.5, B1, B3, C2, BL
Structur 3 in the QuickMix syringe: A1, A2, A3, B1

Indications:
- Fabrication of temporary crowns, bridges, inlays, onlays, partial crowns, veneers and temporary posts
- Fabrication of long-term temporary restorations
- Relining of prefabricated temporary crowns made of composite, polycarbonate or metal

Contraindications:
Structur 3 contains methacrylates, amines, terpenes, benzoyl peroxide, BHT and should not be applied in cases of known allergies to these ingredients.

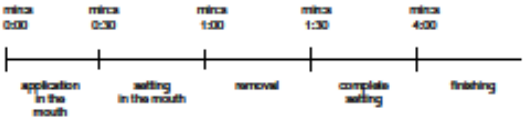
Type of application:

Preparation:

Structur 3 in the cartridge:
Insert **Structur 3** cartridge into the **VOCO** dispenser (type 2) or a comparable dispenser. For technical reasons, there may be slight differences in the filling levels of the two cartridge chambers prior to initial use. In this case, remove the cartridge cap and carefully squeeze the material out until it is delivered evenly from both openings. Then attach a type 6 mixing tip and lock with a 90° turn clockwise. The material is extruded by pressing the lever and is automatically mixed in the correct ratio. After use, do not remove the mixing tip from the cartridge. Do not replace the used mixing tip with a new one until immediately before the next application. When changing the mixing tips, check the openings of the cartridge to ensure that the material can flow freely.

Structur 3 in the QuickMix syringe:
Remove the cap from the syringe by turning it anti-clockwise. Attach a type 10 mixing tip. The slots on the syringe and the mixing tip must correspond. The mixing tip is fixed by rotating it clockwise through 90°. The material is automatically mixed in the correct ratio in the tip as it is dispensed and can be applied immediately. All QM syringes come with a detachable piston. The piston can easily be pulled backwards out of the syringe and then reinserted. The seals in the syringe do not change their position while this is being done. This prevents cross-contamination of the material in the syringe.

Processing directions:
First level out any undercuts in the preparation using a non-eugenol cement.
Take an impression if not using prefabricated dental copings or similar restorative materials.
Prepare the impression by levelling undercuts and cutting drainage channels. If the wall thickness of the temporary restoration is expected to be too thin, enlarge the impression, paying particular attention to removing the sulcuses in the interdental embrasures. In case of gaps in the molar region, cut a groove in the impression to maintain a stable, bar-shaped connection in the temporary restoration.
Then clean and air dry the impression.
Apply **Structur 3** directly into the impression, applying the material initially to the occlusal surfaces of the impression and filling up towards the gingival areas. To prevent the formation of bubbles during application, always keep the opening of the mixing tip immersed in the material. Insert the impression into the mouth no later than 90 seconds after commencement of mixing.
Remove the temporary restoration from the mouth during the elastic phase i.e. within 1 to 1.5 minutes after beginning to mix.
The setting process should additionally be monitored by observing the excess material in the **mouth**.
The setting time of material (in mixing tips) that has not been used cannot be compared to the setting time of the material in the mouth.
The working times at a room temperature of 23 °C and 50% humidity are as follows:



Different room temperatures may result in variations from the above times.
Higher temperatures shorten and lower temperatures extend these times.

Finishing:
Extract the temporary restoration from the impression after 4 minutes at the earliest and completely remove the inhibition layer, caused by oxygen in the air, by wiping with alcohol (e.g. ethanol).
Then carefully grind any excess material and rough areas near the gingiva.
If necessary, finish the temporary restoration with fine, cross-cut carbide burs.
If required, polish the temporary restoration manually (e.g. with a rubber polisher, fine sandpaper or goat hair brush).

Luting:
Carefully clean and dry the core, if necessary removing any insulating material. Attach the finished temporary restorations with a temporary luting cement.
Eugenol cements can inhibit the setting of luting composites that may be used later at the permanent luting stage. If a luting composite is to be used for permanent luting, attach the temporary restoration with a eugenol-free cement.

Instructions for use (Protemp ™ 4

3M ESPE

Protemp™ 4

(en) **Temporization Material**
(de) **Temporäres Kronen- und Brückenmaterial**
(fr) **Matériau provisoire**
(it) **Composito per la realizzazione di provvisori**
(es) **Material para provisionalización**
(pt) **Material de temporização**

Instructions for Use
Gebrauchsinformation
Mode d'emploi
Informazioni per l'uso
Instrucciones de uso
Instruções de uso

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Preparatory Work

- Take an alginate, silicone, or polyether impression from the intact row of teeth.
  - Instead of an impression, a laboratory-made vacuum-formed template or, for single crowns, a preformed crown can be used for shaping.
- To enhance the strength of the temporary restoration, remove interproximal grooves in the impression. If required due to tight spacing conditions, enlarge the relevant sites by cutting.
- For easy replacement in the mouth, relieve undercuts.
- With missing teeth or gaps in the molar area, cut a groove into the impression to produce a stable, bar-shaped connection in the temporary restoration.
- If required, prior to taking the impression close any gaps between front teeth with denture teeth acting as spacers; interlock multiple denture teeth with wax.

Times

00:00–00:40 min:sec	Place Protemp™ 4 into the impression or into the matrix/model and reposition in the mouth
00:40–01:40 min:sec	Setting in the mouth or in the matrix/model
01:40–02:50 min:sec	Best point in time for removal of the impression or of the matrix/model
Up to 05:00 min:sec	Complete setting
From 05:00 min:sec	Removal of the temporary restoration from the impression or from the matrix/model, finishing

The above processing times are applicable to products which have been stored and processed at a temperature of 23° C/74° F and at 50% relative humidity. Higher temperatures shorten these times, while lower temperatures extend them. The size of the restoration also has an impact on the setting times: as the size of the workpiece increases, the setting accelerates.

Dosing and Mixing

The pastes are dosed and statically mixed in the Garant dispenser.

Use the enclosed original Garant™ Mixing Tips Blue only!

During the initial dosing

- **Remove and discard the cartridge lid.** Under no circumstances should the cartridge lid be used to reseal the cartridge as this could result in the inclusion of air bubbles.
- Check whether both cartridge openings are free from obstruction and remove obstructing material, if any, with a suitable instrument.
- Before a mixing tip is applied for the first time, squeeze paste out onto a mixing pad until the base and catalyst pastes are at the same level. Discard the paste which has been squeezed out.

Application

It takes the material a certain amount of time to emerge from the newly attached mixing tip. The flow of material is interrupted as soon as the pressure on the handle is reduced. Material that has set inside the mixing tip should not be extruded by force, as this may damage both the cartridge and the mixing tip. Core build-ups which are fabricated using composites, compomers, or resin-modified glasionomer cements must be sealed off before the application of Protemp™ 4, e. g., using Vaseline.

- First, install a new mixing tip.
- Prior to each application, extrude a small (pea-sized) amount of paste from the mixing tip onto a mixing pad and discard this material.
- Subsequently load the dried impression or vacuum-formed template in the relevant spaces from the bottom up.
- Reposition the impression or vacuum-formed template in the mouth/on the model.
- The material attains a hard-elastic consistency within 1 min 40 sec after the onset of mixing. The material and the impression or vacuum-formed template must be removed from the mouth/model within 2 min 50 sec after the onset of mixing.
- Check the setting process by observing the excess material in the mouth or on the matrix/model.
- Keep the filled mixing tip on the cartridge to serve as a closure until the next use.

Finishing

- Completely remove the oxygen inhibition layer using alcohol (e. g., ethanol) once the material is completely cured (not earlier than 5 minutes after the onset of mixing). Polish if desired, e. g., with Sof-Lex™ polishing disks.
- After the product has cured completely, remove any residues.
- If necessary, finish and polish the temporary restoration using fine carbide burs.
- Do not breathe polishing dust. Use mouth protective device, safety glasses and aspiration.