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Comparative Study *In Vitro* of Acrylic Resins in Fixed Provisional Prostheses

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ABSTRACT

Introduction: Materials for temporary fixed prostheses offer different physical properties in terms of hardness, susceptibility to pigmentation and exothermic reaction during their polymerization.

Objective: To conduct an in vitro comparison of the properties of five acrylic resins for the preparation of fixed provisional prostheses.

Methods: In this study was prepared 30 samples of three different acrylics and five different brands (bis-acryl, auto-cured polymethyl methacrylate and heat-cured polymethyl methacrylate - PMMA), which were tested for exothermic reaction during polymerization, susceptibility to pigmentation and Rockwell hardness.

Results: PMMA had a greater exothermic reaction ($p<0.0001$); bis-acryl showed an increased susceptibility to pigmentation ($p<0.0001$) and heat-cured acrylic was the material with greater resistance ($p<0.0001$).

Conclusion: Auto-cured acrylics are suggested for short periods and non-vital teeth treatments. Heat-cured acrylics are indicated for long-term treatments in long gaps and bis-acryl is indicated for short-term treatments

INTRODUCTION

One of the greatest challenges in dental practice is the handling of provisional prostheses, since the materials available on the market offer different physical properties in terms of resistance, susceptibility to pigmentation and exothermic reaction during their polymerization. Provisional prostheses are restorations designed to protect prepared teeth by simulating the shape and function of permanent restorations. Temporary restorations should provide pulp protection, positional stability, and maintenance of occlusal function, hygiene, strength, retention and aesthetics. These requirements can be subdivided into biological and biomechanical categories [1].

When conducting a biomechanical preparation, the dentinal tubules are exposed; therefore, the internal adaptation, marginal integrity of the temporary restoration and the temporary cementing agent helps to protect the pulp from adverse effects such as bacterial microfiltration and chemical and thermal irritation [2]. It is also important to maintain gingival health and adequate emergency profiles for pontic and abutment sites, considering any periodontal tissues able to be managed.

Provisional restorations should be able to withstand the functional forces of mastication, avoid fractures and displacements and maintain prepared tooth position and stability of inter- and intra-arch relationships through the creation of optimal proximal and occlusal contact. The use of provisional prostheses in aesthetic zones demands greater care and delicacy, since the details will determine the success of the final restoration. The ability of provisional restorative materials to retain color and resist pigmentation is of vital importance, especially when used over long periods of time. Although the problem of pigmentation is common, the effect of different staining agents on resin restorations has not been fully elucidated [3].

There are two techniques for fabricating provisional prostheses. The direct technique consists of making the provisional prosthesis inside the mouth, which involves the polymerization of the acrylic in contact with the tooth and is indicated for short gaps and a maximum of three units. This technique is time-saving. The disadvantages are the exposure of dental tissues to the heat generated during the polymerization and to other irritating chemicals present in the material. The indirect technique, in which the polymerization process is performed by flasking at the dental laboratory, is indicated for long gaps with multiple pontics. The advantage of this technique is the greater control of material contraction, while its main disadvantage is that it requires an intermediate impression and a plaster model, which involves more time and patient, visits [4].

There are different types of materials to make provisional prostheses whose base is acrylic resin. The most commonly used acrylic resins are polymethyl methacrylate, polyethyl methacrylate and bis-acryl. Polymethyl methacrylate is the resin most frequently employed in the direct technique, although one of its disadvantages is that it exhibits an increased shrinkage and it can cause pulp irritation during polymerization. Polyethyl methacrylate is indicated for the indirect technique. Because of its laboratory flasking method, it offers more advantages in terms of resistance and it prevents pulpal irritation. Bis-acryl (Bis GMA) is considered a dual-cure composite, which polymerization occurs initiating a reaction that produces free radicals (aromatic tertiary amine such as dihydroxyethyl-p-toluidine) using an initiator (benzoyl peroxide). Whichever the method of polymerization, no heat is generated when using bis-acryl, as only one bonding of the material which has already been crystallized is carried out [5].

Regardless of the technique (direct or indirect) and the type of the material, dental restoration procedures are decisive in dental practice, as the irregularities in non-polished surfaces promote plaque accumulation and pigment deposition [6].

In vivo investigations have revealed that an increase in pulp temperature of 5.6°C, causes a 15% loss of pulp vitality, while an increase of 11.2°C causes a loss of 60%, and when the temperature reaches 16.8°C, 100% of pulp necrosis can occur [7]. Similarly, Zach and Cohen showed that increasing the pulp temperature by 5.5°C causes considerable damage, resulting in a complete loss of vitality in 15% of the teeth [8].

The objective of this study was to compare different materials for the fabrication of provisional restorations in order for clinicians to be confident that the product being used avoids long-term pigmentation and provides better aesthetic comfort to the patient and hardness to decrease the number of repairs during the treatment, and that the materials are within a safety range that prevents pulp damage on vital teeth.

The null hypothesis of this study is there's no difference between different material in pigmentation, hardness and exothermic reaction.

MATERIALS AND METHODS

One hundred and fifty sample disks with a 2 mm diameter and a 10 mm thickness were made, according to the manufacturer's protocols and indications for each material. For the heat-cured acrylic disks, a liquid/powder mixture was prepared at a rate of 1 gram of polymer per 3 ml of monomer. The material was mixed in a glass dappen dish for 20 seconds. The mixture was then processing according to the temperatures and times indicated by the Nictone® manufacturer (MDC). The brands of the bis-acryl material used for this study were Telio® (Ivoclar Vivadent, Schaan, Liechtenstein) and Versatemp® (Sultan, York, PA). The dispenser gun, cartridge and mixing tip were used with the pre-dosed manufacturer's cartridges, and the mixture was poured in a fluid state into the previously manufactured mold. The brands of auto-cured PMMA used were Nictone® (MDC, Guadalajara, Mexico) and Jet® (Lang; Chicago, Ill). The liquid/powder mixture was prepared inside a silicone dappen dish and poured into the molds in a fluid state.

Twenty-four hours after the polymerization was initiated, the disks were roughened and polished with a Brasseler polishing system. The green, gray and yellow polishers were used intermittently on each side of the disk, at 1500 rpm. The surface was then finished with a pad and white lead on a bench motor at low speed. All of the samples were examined for uniformity, air bubbles or imperfections. Thirty samples from each brand of material were made. Ten samples were used for each test to avoid aging and to maintain uniformity throughout the study.

Measurement of Exothermic Reaction

During the polymerization of the different materials, the maximum temperature increase was recorded using a digital thermocouple. This procedure was only applied to the PMMA and bis-acryl. The sensitive tip was submerged inside the material to be analyzed, which had been placed inside of the sample plate, in order to maintain an amount similar to that necessary to fabricate a provisional unitary prosthesis. The maximum temperature reached during the polymerization was recorded and this procedure was repeated 10 times for each brand.

Measurement of Susceptibility to Pigmentation

The disks were placed on a base in an identical lighting environment. The initial tone was recorded using a spectrometer (VITA Easy shade®), as although during the whole process we worked with A2 tone materials, it was necessary to verify the initial color by means of the spectrophotometer. The 10 samples of each brand were then immersed for 24 hours in three different beverages (orange juice, coffee and red wine). After each submersion, the samples were washed with water and a toothbrush. To record and quantify the color change, the Delta E* value was determined. The use of a spectrophotometer and colorimeters is a quantifiable digital method in color analysis. Through this method, the L*, a* and b* values were measured in digital images using a specialized software and the correlation determined with the spectrophotometer was reported. L* represents the darkest black at L*=0, and the brightest white at L*=100; a* and b* are chromaticity coordinates between the red/green axis and the yellow/blue axis. On the* axis, positive values indicate a range of red, while negative values indicate a range of green, and on the

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b* axis, positive values indicate a range of yellow, while negative values indicate a range of blue. Currently, the pigmentation has been stabilized using spectrophotometric analysis. The color difference is calculated as DELTA ΔE*, which is given by the software. A value lower than ΔE* 3.7 is imperceptible by the human eye [9].

Hardness Test

For this test, new samples were processed simultaneously to ensure the aging time was the same for all of them. The hardness was measured using a durometer. Rockwell B Hardness (HRB) is a method for measuring hardness, which is the resistance of a material to penetration. The test consisted of placing the acrylic sample on a completely flat surface of the device, using a spherical penetrating tip to penetrate 1/16 inch tempered and polished hardened steel. A pre-load of 10 kg was applied to eliminate elastic deformation; thereafter, a static load of 60 kg of compression was applied for 90 seconds to all the materials analyzed. The load was then released and the hardness considered as the penetration by diamond tip on the specimen, was measured using a durometer.

Statistical Analysis

The quantitative variables were summarized in means and standard deviation. The normal distribution of the data was assessed using the Kolmogorov–Smirnov test. The materials were compared by an ANOVA test and Tukey's post-hoc test. The level of significance was lower than 0.05. Statistical analysis was performed with the SPSS statistical package.

RESULTS

The response to the three tests performed on the disks made from different materials is shown in **Table 1**. **Table 2** shows a comparative analysis between the brand and the three different materials that were tested.

Susceptibility to Pigmentation

Bis-acryl was the most pigmented material with values of 5.9 to 6.6 ΔE*, followed by heat-cured acrylic with an average of 4.4 to 5.6 ΔE*. The material with the lowest pigmentation was self-cured acrylic, with an average of 3.2 a 4.2 ΔE*; the differences were statistically significant. Orange juice showed the highest values of pigmentation in all of the materials. Nictone (MDC) showed the lowest susceptibility to pigmentation and the most susceptible to pigmentation brand was Telio (Ivoclar Vivadent) (p<0.0001).

Exothermic Reaction

Self-cured acrylic produced higher heat than Bis-acryl (p<0.0001), exhibiting a difference of up to 18°C **(Table 1)**. The PMMA Nictone material reached values of up to 55°C. The Nictone (MDC) and Jet (Lang) materials generated the highest heat showing no statistically significant differences between them and reaching an average of 54°C.

Table 1. Comparison of three materials according to their composition.

	Self-cured Acrylic Mean (SD)	Bis-acryl Mean (SD)	Heat-cured Acrylic Mean (SD)	F	p
Orange juice ΔE*	4.2 (1.9)[b]	6.7 (2.6)[b]	5.6 (0.6)	7.32	0.001
Coffee ΔE*	3.3 (2.2)[b]	5.9 (1.3)[b]	4.4 (0.6)	10.4	0.0001
Red Wine ΔE*	3.5 (2.4)[b]	6.6 (0.9)[bc]	4.8 (0.4)[c]	18.3	<0.0001
Heat °C	54.0 (6.1)	36.4 (1.3)	-	11.3	<0.0001
Resistance HRB	18.5 (14)[b]	10.0 (1.8)[b]	73.3 (6.0)[b]	406	<0.0001
ΔE*= Delta E pigmentation, HRB= Rockwell B Hardness, a=No significant, b=p<0.0001 (Tukey's post-hoc test), c=p=0.01					

Hardness

The material with the highest hardness value was heat-cured acrylic, with 73.3 HRB. It showed a statistically significant difference of p<0.0001 with the other two materials. The Jet (Lang) self-cured acrylics reached the highest hardness values with an average of 26 HRB, while there was no significant difference between the two brands of bis-acryl, with an average of 10 HRB **(Table 2)**.

Table 2. Comparison between 5 groups according to each trademark.

	Nicton Mean(SD)	Jet Mean(SD)	Versatemp Mean(SD)	Thelio Mean(SD)	Termo Mean(SD)	F	p
Orange juice ΔE*	2.8(1.8)[b]	5.6 (0.5)[ab]	4.2 (0.4)[ab]	9.1 (0.6)[b]	5.0 (0.6)[ab]	61.3	<0.0001
Coffee ΔE*	1.3 (1.2)[b]	5.3 (0.5)[ab]	4.1 (0.7)[ab]	7.5 (0.4)[b]	4.5 (0.6)[ab]	87.3	<0.0001
Red wine ΔE*	1.2 (0.2)[b]	5.8 (0.8)[ab]	5.9 (0.3)[ab]	7.4 (0.6)[b]	4.8 (0.4)[b]	217.5	<0.0001
Heat °C	55.3(6.3)[a] b	52.6(5.8)[ab]	36.9 (1.4)[ab]	35.8(0.7)[ab]	-	54.8	<0.0001
Hardness HRB	10.8(1.8)[a] b	26.2(2.2)[b]	10.0 (2.0)[ab]	10 (1.6)[ab]	73.3(6.0)[b]	717.1	<0.0001
ΔE*=Delta E pigmentation, HRB=Rockwell B Hardness, a=No significant, b=p<0.0001 (Tukey's post-hoc test)							

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DISCUSSION

This study shows that bis-acryl generated less heat during polymerization than self-cured acrylics, which means that there is less risk of causing tissue damage to the tooth and surrounding tissues. Identifying the material that produces less heat during polymerization lowers the likelihood of pulpal damage. In this study, a direct measurement of the temperature of the provisional material was carried out, reducing the margins of error by standardizing the temperature of the thermocouple sensor embedded in the center of the specimen to be polymerized. We have to take into consideration that if the material is in close contact with dentin tubules and the distance to the pulp, it is not possible to perform a clinical measurement. Other studies where the sensor was not in direct contact with the materials during the polymerization have shown different values [10-12]. The polymerization process in bis-acryl is based on the action of free radicals at the onset of the reaction. For these free radicals to be generated, an external stimulus is required. This stimulus originates from the mixture of two pastes, one of which contains a chemical activator (aromatic tertiary amine such as dihydroxyethyl-p-toluidine) and the other, an initiator (benzoyl peroxide), which avoids the generation of heat, as only one bonding of the material which has already been crystallized is carried out. Chiodera proposes refrigerating the silicone matrix for 30 minutes, prior to fabricating a provisional prosthesis using the direct technique, which decreases the exothermic reaction by nearly 12 °C, although it increases the polymerization time [11].

The bis-acryl acrylic resin was the material with the highest susceptibility to pigmentation, followed by the heat-cured acrylic resin and lastly, the material with the lowest susceptibility to pigmentation was self-cured PMMA, which had low values, hardly perceptible to the human eye. The drink with the highest pigmentation level was orange juice, with at least one value more than the rest of the drinks used in this study. Ertas reported that the average consumption of a cup of coffee is 15 minutes; thus, subjecting the samples to this substance for 24 hours, equals to two months in the mouth, considering 1.6 servings of coffee a day (two cups) [13]. Pigmentation of dental materials may be due to extrinsic factors, such as surface roughness, poor oral hygiene, food consumption and wear of materials, and intrinsic factors, such as the filling composition of monomers or residual monomers not polymerized due to an incomplete polymerization. Methyl methacrylate resin materials contain a more homogeneous composition compared to bis-acryl resins. Another element that is capable of improving the properties of the materials is the use of varnish at the end of the polishing phase, for this can reduce the porosity of the material and decrease its susceptibility to pigmentation. This increases the benefits of surface polishing and decreases the buildup of dento-bacterial plaque [14]. Since it is difficult to achieve a durable polish in bis-acryl, this material is more susceptible to pigmentation. Conventionally polished bis-acryl will easily loose its luster if rubbed, due to its oxygen-inhibited layer, which makes a surface more unstable.

Hardness values have been used to measure the mechanical properties of materials and, therefore, predict the wear resistance of many restorative materials including acrylic teeth [15]. According to the results obtained from the indentation test, heat-cured acrylics showed much higher hardness values, thus being the most suitable material to be used for longer periods of time. Hae-Hyoung Lee obtained lower hardness values using a Barcol test, as they exerted a force of up to 90 N, while in the present study only 60 N were applied [16]. The process by which these materials are processed has a significant effect on their strength, as heat-cured acrylic (ethyl methacrylate) is processed through heat activation and compression molding (flasking), which creates a homogeneous and bubble-free mixture, with higher resistance in comparison to the other materials we studied.

CONCLUSION

Because of their hardness and functional stability, heat-cured acrylics (ethyl methacrylate) are suggested for periods longer than one month, whereas self-cured acrylics (methyl methacrylate) are suggested for direct temporization for replacement of single teeth, (up to three units), with a minimum dentin thickness of 1 mm, using cooling techniques during polymerization, or on non-vital teeth, to avoid the risk of excess heat.

Bis-acrylics are materials that can only be used temporarily (up to 15 days) as they are very weak and highly susceptible to pigmentation. However, bis-acrylics have very good handling and temperature characteristics.

Based on our study, clinicians should carefully evaluate each case before opting for any of these materials.

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