Journal of Oral Health & Dentistry
JOHD, 3(2): 217-221
www.scitcentral.com

ISSN: 2638-499X

Original Research Article: Open Access

Do Different Characterization Techniques for Eye Prosthesis Affect the Physical and Mechanical Properties of Acrylic Resin?

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Received January 23th, 2020; Revised January 28th, 2020; Accepted January 30th, 2020

ABSTRACT

Purpose: To evaluate the effect of ocular prosthesis characterization techniques on the physical and mechanical properties of acrylic resin.

Materials and methods: The response variables were porosity, roughness and micro hardness. Thirty circular specimens (3 mm × 12 mm) were distributed among three groups: Control: Acrylic resin in color N1 (Classical Dental Articles Ltd., Campo Limpo Paulista, SP, Brazil) + colorless acrylic resin (RAIT); DCG: N1 + direct characterization with red acrylic pigment and monopoly + RAIT; ICG: N1 + indirect characterization with red acrylic pigment + RAIT. The variables were measured after polishing the specimens with felt disks, pumice stone and white from Spain in polishing machine. To quantify the porosity percentage in inverted microscope and NIS Elements Basic Research software, four readings were performed. The roughness test (roughness; cut off 0.8 mm/4.8 mm area) followed the standard ABNT/NBR/ISO 4287: 2002, with 3 measurements and a final average. For Knoop micro hardness (Micro hardness Tester Shimadzu, 25g/5 s loads), 4 measurements and a final average was obtained. For porosity analysis, Kruskal-Wallis test was used ($p<0.05$); for roughness and hardness the one-way Anova Test was used ($p<0.05$).

Results: The G2 group showed the lowest percentage of porosity, being statistically different from the others, which were similar to each other ($p=0.00$). There was no significant difference. Between groups for roughness ($p=0.303$), G2 group showed lower micro hardness when compared to control and G1 group showed intermediate values ($p=0.020$).

Conclusion: Indirect characterization provided lower porosity and micro hardness compared to the direct technique.

Keywords: Junctional epithelium, ICAM, Enamel organ, Papillary layer

Abbreviations: RAIT: Colorless Acrylic Resin; N°: Number; mm: Millimeter; °C: Degree Celsius; CG: Control group; Ø: Diameter; DCG: Direct Characterization Group; g: Gram; ICG: Indirect Characterization Group; s: Second

INTRODUCTION

Among the facial rehabilitation modalities, the ocular prosthesis can be indicated for individuals who have ocular deficiencies, and it can be obtained by different methods, among which can be cited the conventional method and partial or total digital flow method. The methods that use the digital flow are of relatively new use in this area and the literature indicates pilot studies and case reports [1-4]. For this digital protocol to be applied, specific and costly equipment is required, selection of a biocompatible material that can be printed, in addition to the printed surface must be smooth and homogeneous. For semi-automated methods, an experienced professional is still required to complete the process and digital flow techniques require skill and software for 3D graphics and modeling [4]. In the conventional method, the prostheses are obtained in heat cured acrylic resin from the ophthalmic cavity mold [5-6]. With the characterization using pigments in the scleral portion [1,7,8] and the iris with details and colors similar to those of the patient [9] to be aesthetically appropriate. For this method, the clinical and laboratory techniques and protocols used are already well established, the materials are easy to purchase and are more affordable. However, some clinical difficulties may occur during the patient's adaptation process to the prosthesis, such as increased secretion, local

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Citation: da Silva CHL & Magdalena CMAP. (2020) Do Different Characterization Techniques for Eye Prosthesis Affect the Physical and Mechanical Properties of Acrylic Resin? J Oral Health Dent, 3(2): 217-221.

irritation, itching [10,11] and color change, which may be related to the preparation technique and material characteristics. Among the stages of making using the conventional method, a critical and important step is the characterization of the sclera.

For the characterization, it is necessary to use a monomer, which may be related to the patient's discomfort and also to changes in the porosity, roughness and hardness of the acrylic resin due to the release of increased amounts of residual monomer [12,13]. Thus, the objective of the study was to carry out an in vitro study to evaluate the effect of different techniques for characterizing the ocular prosthesis on the porosity, roughness and hardness of the acrylic resin.

MATERIALS AND METHODS

Specimen preparation and group formation

To obtain the specimens, circular wax patterns N°9 (polidental, Industria e Comércio Ltd., Cotia, SP, Brazil) with 12 mm diameter and 3 mm, 2 mm or 1.5 mm thickness were obtained and included in a teflon box with hard silicone (Zetalabor, Zhermack, Rovigo, Italy). After the silicone polymerization, the set was included in metal flask no. 6 (OGP Produtos Odontológicos Ltda., Sao Paulo, SP, Brazil) and stone type III (Asfer, Indústria Química Ltda, Sao Caetano do Sul, SP, Brazil). After setting the plaster, the wax patterns were removed, obtaining the mold to make the specimens.

Heat-cured acrylic resin in color N1 (Artigos Odontológicos Clássico Ltda., Campo Limpo Paulista, SP, Brazil) was manipulated, packed into the molds, pressed and polymerized following the manufacturer's instructions. The set was taken to a 1,100 Kgf hydraulic press for 60 min. The polymerization was performed in an automatic polymerizer (Termocycler 100, Precision Workshop, Campus of Ribeirão Preto, University of São Paulo, Ribeirão Preto, Brazil) in a water bath. The flask was placed in water at room temperature and after 20 min reached 73°C, which was maintained for 1 h; then the temperature was raised to 94°C in 20 min and temperature maintained for half an hour.

After polymerization, the specimens were trimmed with straight piece (Dabi Atlante, Ribeirão Preto, Brazil) and multilaminated cutters (Maxicut, Malleifer AS, Ballaiguer, Switzerland) and the polishing on both the sides was performed with 220, 320, 400 and 1200 grit water sandpaper for 10 s on each side and for each sandpaper (Norton, Norton Saint-Gobain, Guarulhos, Brazil) in horizontal polishing (Arotec, Aropol E, Cotia, SP, Brazil).

The specimens in different thicknesses (3 mm, 2 mm or 1.5 mm) were distributed in groups according to the technical characteristics, as follows:

Control group (cg): N1 heat-cured acrylic specimens with Ø 12 mm × 2 mm were positioned in mold with Ø 12 mm × 3 mm of high for pressing colorless acrylic resin (Clássico Artigos Odontológicos Ltd., Campo Limpo Paulista, SP, Brazil). The colorless acrylic resin was proportioned and handled according to the manufacturer's instructions, and the pressing, polymerization and finishing process followed the same rules as for N1 acrylic resin. At the end, the specimens with 2 mm of N1 resin and 1 mm of colorless resin were polished with conventional discs felt, pumice and white of Spain, washed in running water and kept at room temperature for 24 h.

Direct characterization group (dcg): N1 acrylic resin specimens with Ø 12 mm × 1.5 mm of thicknesses were positioned in mold with Ø 12 mm × 3 mm of high. A layer with 0.015 g of red acrylic pigment (Clássico Artigos Odontológicos Ltda., Campo Limpo Paulista, SP, Brazil) and 0.004 g of monopoly (gel obtained by baking 21 g of monomer and 4 g of polymer in a water bath at 50°C), weighed on a precision balance (Mettler Toledo, Greifensee, Switzerland), was applied to the exposed surface of the specimen by the brush addition technique. After 24 h at room temperature, a colorless acrylic resin layer was polymerized on the set. At the end, specimens with 1.5 mm of N1 resin, 0.5 mm pigment and 1 mm colorless resin were polished and finished as described for the Control Group.

Indirect characterization group (icg): 0.015 g of red acrylic pigment, weighed in a precision balance, it was deposited on the bottom of the empty mold with Ø 12 mm × 2 mm of high. In the plastic phase, N1 acrylic resin was deposited in the molds and the polymerization, finishing and polishing steps followed the protocols already mentioned. Then the specimens were repositioned in the Ø 12 mm × 3 mm of high molds with the pigmented layer facing the exposed muffle surface and received a 1 mm layer of colorless acrylic resin. At the end, the specimens were polished with discs of felt, pumice and white of Spain around conventional, being washed in running water and kept at room temperature for 24 h, to be submitted to the tests.

Variables

Surface porosity: The colorless surface of the specimens was divided into quadrants and an image of each quadrant was obtained for each specimen with the aid of the Nikon Eclipse MA100 inverted microscope (Nikon Corporation, Japan, Kawasaky, Kanagawa) with a 20x with NIS Elements Basic Research software (Nikon Corporation, Japan, Kawasaky, Kanagawa). Images were processed (Photoshop, 14 64-bit software, Adobe Photoshop, United States, San Jose, California) to reduce background and shadows. Then the images were converted to clean binary format images (Image J 1.45s software, National Institute of Health, Bethesda, Maryland, USA) and the dark region area, which represents the porosity, was calculated with the calibrated program for the microscope scale. The porosity area percentage was calculated for each quadrant in relation to the total image area. At the end, an average of four percentages was obtained.

Surface roughness: The test followed the standard ABNT/NBR/ISO 4287: 2002. The roughness test was performed using a Surface Roughness Tester SJ-201P (Mitutoyo Corp, Kawasaki, Japan) with 5 cut off 0.8 mm in each reading. that the needle tip traveled 4.8 mm with a reading speed of 0.5 mm/s, considering 0.4 mm for acceleration and 0.4 mm for needle deceleration during reading. Three colorless surface measurements were obtained, one central, one at 1 mm to the right and one at 1 mm to the left of the center. The mean of 3 measurements was used as the roughness value for each specimen.

Surface micro hardness: The colorless surface of each specimen was divided into quadrants and the micro hardness was analyzed with the aid of the Micro hardness Tester Shimadzu - HMV-2 microdurometer (Shimadzu Corporation, Kyoto, Japan) with a 25 g load for 5 s in each reading. At the end, the micro hardness was calculated based on the average of the four readings.

DATA ANALYSIS

Data was analyzed using SPSS 21.0 statistical software (IBM Corp. released 2012, IBM SPSS Statistics for Windows and Version 21.0 - Armonk, NY, IBM Corp). All tests were performed with a 95% confidence level. After analyzing the distribution of data regarding the normality curve (Levene test) and homogeneity (Shapiro-Wilks test), the statistical tests to be employed were defined; Porosity data were analyzed by Kruskal Wallis test and post-test Dunn and surface roughness and micro hardness data were analyzed by Anova One-Way Test and TukeyPost-Test.

RESULTS

Table 1 presents the analysis of the porosity percentage found in the control group (CG) and in the direct (DCG) and indirect (ICG) characterization groups, as well as descriptive statistics and statistical comparison of results. Statistical difference (p=0.00) was observed between the groups. ICG group showed the lowest porosity percentage and, the CG and DCG groups were similar to each other.

Table 1. Mean standard deviation (SD), median and confidence interval (CI) of porosity percentage in each group.

	CG	DCG	ICG	P*
Mean	0.15	0.71	0.06	
SD	0.05	0.81	0.04	0.00
Median	0.14 A	0.46 A	0.04 B	
CI	0.11-0.19	0.10-1.33	0.02-0.09	

**Kruskal-Wallis Test and Dunn Post test. Equal capital letter indicates statistical similarity*

For surface roughness of the specimens, there was no statistical difference (p=0.303, Anova One-way test) between CG (0.23 ± 0.05), DCG (0.21 ± 0.09) and ICG (0.18 ± 0.06) groups. Therefore, surface roughness was not influenced by the characterization technique.

For the micro hardness comparison of data, statistical test (indicated significant difference between groups (p=0.020; Anova One-way test). The control group (18.02 ± 0.98) exhibited the highest values and the ICG group (15.96 ± 0.83) exhibited lowest values. The DCG group (17.42 ± 0.89) shows intermediate values.

DISCUSSION

There are few studies on the effects of the techniques used on ocular prosthesis materials [14-18]. However, the relationship between the method and medium used for polymerization is already established in the literature, as well as the maximum pressure and temperature reached during the polymerization cycle on the physical and mechanical properties of the acrylic resin, which may impair the quality, durabilityand function [19,20].

It is also known that the porosity in the acrylic resin is inversely proportional to the strength of the material and, if the pores are exposed on the surface, this promotes greater roughness and a consequent increase in the adhesion of microorganisms [21,22]. Therefore, the control of these properties to clinically acceptable levels is extremely important to guarantee the durability of the prosthetic appliance, with less contamination and less risk of tissue irritation. Porosity is a failure well described in the literature, and its causes arise from the processing of the material such as thermal expansion/contraction of plaster or acrylic resin, polymer/monomer ratio, pressure used during pressing, size and thickness of the prosthesis, absorption or water loss, polymerization cycle [19,20]. In order to avoid porosity, the manufacturer's instructions must be followed, which was strictly complied with in this study, with a difference only with regard to the characterization techniques. For the indirect technique, the acrylic pigment was added to the flask and incorporated into the N1 acrylic resin mass during pressing and polymerization. For the direct technique, the acrylic pigment was mixed with the monopoly gel and the whole deposited on one of the surfaces of the specimens. This process may have favored the formation of pores in the GCI due to the greater amount of residual monomer. The results show that the porosity was higher for the group without characterization and for direct characterization,

when compared to the group of indirect characterization, suggesting that the change in the polymer/monomer ratio necessary for the performance of the characterization techniques may have influenced. It should be noted that, although the specimens received a layer of colorless acrylic resin and a second polymerization, this process was not effective in preventing the formation of pores. These are important results because they present an analysis not yet described in the literature and because the control of porosity is an important factor for the stability of other properties of the material. When in contact with the aqueous medium, the material absorbs liquid in an amount proportional to the number of pores; occupying the empty spaces the liquid expands the final volume of the polymer [19,23,24]. And as a consequence affects other properties of the material such as roughness and micro hardness [21,22,25].

Roughness can be affected by improper handling of the polymer and monomer, by excess of monomer and inadequate pressure during the processing or polishing of the material [19]. This property can be measured in order to assess the quality and clinical performance of a material, since, if it is at increased levels, it will impair aesthetics by staining the prosthesis resulting from the accumulation of biofilm and liquid absorption [26-28]. The results found in this study demonstrated that the characterization techniques did not influence this property and the values are within clinically acceptable [29-30]. Roughness values above Ra=0.2 μm favor an increase in microbial colonization with the biofilm formation, and the roughness protects this biofilm against cleaning [28], helping its maturation with a consequent increase in the risk of infections and tissue injuries. The polishing used in the specimens may justify the results; however, it is necessary to have a long-term follow-up in order to confirm them, since according to the literature this property can be affected by aging [16,17].

The Knoop micro hardness property is related to the forces of plastic deformation, wear and deterioration and is clinically relevant because it is associated with the material's ability to maintain polishing [19] and to resist abrasions and wear over time. For this property, the results showed a significant difference between the groups, with the highest value found in the group without characterization, the indirect characterization group with the lowest micro hardness values and the direct characterization group with intermediate values. However, although this property has been affected, the values obtained can be considered clinically acceptable for the material. According to specification no. 33 of the American National Standards Institute (ANSI)/American Dental Association (2003), the minimum hardness for acrylic resin for artificial teeth should be fifteen. Considering that no critical value has been found for acrylic resin for ocular prostheses and that artificial teeth are subjected to masticatory load and abrasion, which is not the case with ocular prostheses, the values can be considered as a reference base in the study.

One of the limitations of the study is related to the measurement of properties in one time; however the answer regarding the influence of characterization techniques on properties over time can be obtained by conducting studies that favor monitoring for a longer period of the time.

CONCLUSION

Considering the results and limitations of the study, it can be concluded:

1. The indirect characterization technique promoted less pore formation when compared to the direct characterization technique.
2. The roughness of the material was not affected by the application of the different characterization techniques.
3. The material hardness was lower with the use of the indirect characterization technique; however, the values obtained are clinically acceptable.

ACKNOWLEDGMENT

Adriana Claudia L. Faria Queiroz; Ana Paula Macedo; Rafaella Tonani; Viviane de Cássia Oliveira.

CONFLICT OF INTERESTS

None declared.

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