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Color and surface gloss stability of bis-acryl and resin composite after exposure to cigarette smoke

Estabilidade de cor e brilho superficial de resinas compostas e bisacrílicas após exposição por fumaça de cigarro

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ABSTRACT

Objective: To evaluate color and surface gloss stability of bis-acryl resins and resin composites, submitted to artificial staining with cigarette smoke. **Material and Methods:** Specimens of each material were prepared (n=15). Two resin composites (GrandioSO [RCG], Filtek Supreme [RCZ]) and five bis-acryl resins (Luxatemp Star [BisLUX], Protemp4 [BisPRO], Structor3 [BisSTR], Visalys Temp [BisVIS] and Yprov [BisYPR]) were tested. Initial color was assessed using a spectrophotometer and surface gloss with a glossmeter. Samples were submitted to smoke exposure (10 cigarettes under 8 minutes per cycle). After 3 and 6 cycles, color and gloss were reassessed. Final readings were performed after brush prophylaxis. Data were analyzed using two-way repeated ANOVA and Tukey's test ($p<0.05$). **Results:** Differences and interaction of factors ($p<0.01$) were detected for both color and gloss readings. Resin composites were the least affected by aging, with gloss reduction after prophylaxis. Differences were detected among bis-acryl resins, with better results for BisLUX and BisPRO. BisPRO and BisSTR, showed reduction in gloss after 60 cigarettes, while BisYPR gloss decreased at all evaluated periods. **Conclusion:** Resin composites are less susceptible to changes after smoke exposure, while bis-acryl resins results are brand-dependent. Prophylaxis negatively influenced the surface gloss of most of the tested materials.

KEYWORDS

Bis-acryl resins; Color; Composite resins; Smoke; Temporary dental restoration.

RESUMO

Objetivo: Avaliar a estabilidade de cor e brilho superficial de resinas compostas e bisacrílicas, submetidos ao manchamento artificial por fumaça de cigarro. **Material e Métodos:** Foram preparados espécimes de cada material (n=15). Duas resinas compostas (GrandioSO [RCG], Filtek Supreme [RCZ]) e cinco resinas bisacrílicas (Luxatemp Star [BisLUX], Protemp4 [BisPRO], Structor3 [BisSTR], Visalys Temp [BisVIS] e Yprov [BisYPR]) foram testados. A cor inicial foi avaliada usando um espectrofotômetro e o brilho de superfície com um medidor de brilho. As amostras foram submetidas à exposição de fumaça de cigarro (10 cigarros com até 8 minutos por ciclo). Após 3 e 6 ciclos, a cor e o brilho foram reavaliados. As leituras finais foram realizadas após a profilaxia escova de robinson. Os dados foram analisados usando de medidas repetidas e teste de Tukey ($p<0,05$). **Resultados:** Foram detectadas diferenças e interação de fatores ($p<0,01$) tanto para leituras de cor quanto para leituras de brilho. As resinas compostas foram as menos afetados pelo envelhecimento, com redução do brilho após a profilaxia. Foram detectadas diferenças entre as resinas bisacrílicas, com melhores resultados para BisLUX e BisPRO. BisPRO e BisSTR, mostraram redução de brilho após 60 cigarros, enquanto que o brilho da BisYPR diminuiu em todos os períodos avaliados. **Conclusão:** As resinas compostas são as menos suscetíveis a mudanças após a exposição à fumaça, enquanto os resultados das resinas bisacrílicas são dependentes da marca. A profilaxia influenciou negativamente o brilho de superfície da maioria dos materiais testados.

PALAVRAS-CHAVE

Resinas bisacrílicas; Cor; Resinas compostas; Fumaça; Restauração dentária temporária.

INTRODUCTION

Temporary restorations are essential in esthetic treatments and/or major rehabilitations, especially when anterior teeth are involved in process [1,2]. Provisional prosthesis assists the treatment diagnosis, and it allows the evaluation of teeth contours, size, shape and color. The occlusal guides at this stage of treatment are also evaluated with the use of temporary restorations, increasing the predictability of the final result [1,2]. During the interim phase of the treatment, provisional prosthesis maintains the function and esthetics up to the final phase with cementation of the final restorations [1,2]. Still, provisional prostheses are of great importance in maintaining the periodontal health and to possibly guide tissue healing, favoring the final adaptation of the prosthesis [1-3]. They should not be replaced by permanent restorations until all treatment objectives have been achieved [2].

The provisional restoration should be as similar as to definitive restoration in all aspects, except in relation to material it is fabricated. Several materials are indicated for making provisionals, however, there is no consensus regarding the best restorative material that meets the ideal requirements for all situations [1,2,4-6].

In this context, bis-acryl resins are an excellent option [2]. This group of resin has bifunctional acrylates that provide greater mechanical resistance as cross-links are formed [2,6,7]. In addition, the presence of inorganic content decreases the polymerization shrinkage and increases the resistance of the material to abrasion [6,7]. Cross-link characteristics combined with inorganic particles facilitate its use and the polishing properties of restorations [2,6].

In clinical practice, provisional restorations may remain in function for days or even months [1]. Therefore, the restorations must perform well during the time required up to the final stages of the treatment, with no significant changes in surface. In case provisional materials are not stable, the replacement of the restoration may be required, which can cause dissatisfaction and increased treatment costs [1].

A frequent concern of professionals employing provisional restorations should be when treating smoking patients, since according to the World Health Organization (WHO) [8], there are approximately 1 billion smokers in the world. It is reported that cigarette smoke is able to alter and/or stain the surface of resin composite [9] or acrylic resins [10], used in total or removable dentures. The staining occurs once the thousands of toxic substances present in cigarettes, such as nicotine, carbon monoxides, ammonia, nickel, arsenic, lead and cadmium, are able to impregnate to the material's structure, leading to esthetic damage [11-13]. Regarding bis-acryl resins, there are no studies that assess color stability after cigarette smoke, and whether prophylaxis with abrasive products would be able to remove the pigments adsorbed on the surface. The comparison between bis-acryl resins (temporary) and resin composites (final restorative material) aged by cigarette smoke is another factor that has been no studied.

Thus, the objective of this study was to evaluate the optical properties of a group of resin composites and bis-acryl resins submitted to aging by cigarette smoke, regarding the color and surface gloss stability. The study also evaluated the effect of prophylaxis with abrasive paste for possible stain removal. The tested null hypotheses were: There is no difference between the types of materials in relation to changes of color or surface gloss; There is no change in color or surface gloss after each evaluation period (after the 3rd and 6th exposure to smoke and after the prophylaxis of the stained specimens).

MATERIALS AND METHODS

The study factors were: 2 resin composites and 5 bis-acryl resins under 3 assessment periods (after the 1st exposure [30 cigarettes], after the 2nd exposure [60 cigarettes] and after prophylaxis). The specifications of the materials used are described in Table 1.

Sample size calculation

Sample size was calculated using G * Power 3.1 software, with mean and standard deviation data from a pilot study that resulted in an effect size of 0.583. Using α at 5%, β at 80% and effect size of 0.583, 13 specimens per group were required.

Resin composite specimen preparation

Fifteen specimens were fabricated of each resin composite. The samples were made using a device consisting of a metallic base and split

Table 1 - Characteristics of materials used in the present study

Interim materials	Manufacturer	General composition[a]	Shade
GrandioSO (RCG)	Voco	Bis-GMA, Bis-EMA, TEGDMA, 89% glass ceramic, silicon dioxide	A1E
Filtek Supreme (RCZ)	3M ESPE	Bis-GMA, UDMA, TEGDMA, methacrylate, 78,5% sílica, zircônia, aggregated zircônia/silica	A1E
Luxatemp (BisLUX)	DMG	Glass filler in a matrix of multifunctional methacrylates, catalysts, stabilizers and additives. Free of methyl methacrylate.	A1
Protemp 4 (BisPRO)	3M ESPE	Dimethacrylate polymer. Bis-GMA, zirconium particles, silica and silane, pigments.	A1
Structur 3 (BisSTRU)	Voco	Bis-GMA, BHT, amines, benzoyl peroxide, dimethacrylates, glass particles	A1
Visalys Temp (BisVIS)	Ultradent	Multifunctional acrylic Composite, free of bisphenol A and its derivatives	A1
Yprov bisacryl (BisYPR)	Yller	Methacrylate, catalyst, 40nm inorganic nanoparticles, stabilizers	A1

[a]Information provided by the manufacturers.

matrices with orifices of 6mm in diameter and 2mm thickness.

The resin composite was inserted in a single increment and a mylar strip and a glass slide were placed on top of it to remove excess and flatten the surface. Lightcuring was performed for 40 s with an LED light (VALO - Ultradent Products Inc, South Jordan, UT, USA) at 1000 mW / cm2, measured by means of a radiometer.

All specimens were polished with #800, #1200 and #2400 sandpaper discs (Fepa-P, Extec, Enfield, CT, USA), mounted in a polishing machine (DP10, Panambra, São Paulo, SP, Brazil) for 30 s each, at 300 rpm speed under 100 gram-force load and distilled water irrigation. The specimens were stored for 24 h at 37ºC and 100% humidity in individual vials.

Bis-acryl resin specimen preparation

Fifteen specimens were fabricated from each bisacrylic resin. Polyvinyl siloxane matrices with 6mm in diameter and 2mm thickness orifices were used. The resin was inserted into the orifices, covered with a mylar strip, and pressed with a glass slide to remove the excess materials and to prevent bubble formation. The setting time of materials was 5 min. To guarantee complete polymerization, the specimens were stored for 24 h at 37ºC and 100% humidity. The surface inhibition layer was removed after the material was fully cured by rubbing gauze soaked with ethanol, following the manufacturer's recommendation.

Color assessment

The baseline color of each specimen was assessed under standardized ambient conditions, using a spectrophotometer (CM2600d. Konica Minolta. Osaka. Japan) with an integrating sphere, according to the Commission Internationale de l'Eclariage (CIE) Lab system. The device was adjusted to use the D65 standard light source with 100% ultraviolet (UV) light and specular component included (SCI). The evaluation was performed under reflectance on a white background L: 84.95; a: 0.38; b: 2.93. The observer angle was set at 2º and the device was adjusted to a small reading area (SAV). The color of each sample was measured four times and averaged at each evaluated period (baseline, after 30 and 60 cigarettes exposure and after prophylaxis).

The values of the changes in L* (ΔL). a*(Δa). and b*(Δb) were calculated from the color measurement between baseline and the assessments after the cigarette smoke exposures (30 and 60) and after prophylaxis. Next, the total change in color was calculated using the $CIEDE_{00}$ (ΔE_{00}) equation as follows:

$$\Delta E00 = \left[\left(\Delta L' / KLSL \right)2 + \left(\Delta C' / KCSC \right)2 + \left(\Delta H' / KHSH \right)2 + RT \left(\Delta C' / KCSC \right) \Delta H' / KHSH \right]^{1/2} \quad (1)$$

where ΔL', ΔC', and ΔH' are the differences in lightness, chroma, and hue; and RT is a function (rotation function) that accounts for the interaction between the chroma and hue differences in the blue region. The weighting functions SL, SC, and SH adjust the total color difference for variation in the location of the color difference in L*, a*, and b* coordinates. The parametric factors KL, KC, and KH are correction terms for experimental conditions.

Surface gloss assessment

Gloss was measured using Novo-Curve (Rhopoint TM) glossmeter with a 2mm X 2mm square area and 60° of geometry (light incidence), and values are expressed in gloss units (GU). A metallic positioner was used to block and eliminate possible environment light interference. Three random measurements were performed per specimen at each evaluated period. Means values obtained were used as the final gloss value. Gloss variations (ΔGU) between baseline and each evaluated period were also calculated to compare the results to the reported limits of acceptability and perceptibility of gloss variations.

Cigarette smoke exposure

To expose the specimens to the cigarette smoke, a hermetically closed acrylic box was used to mimic the smoking activity inside the mouth. The box presented two chambers separated by a plate with 10 orifices for the cigarettes. The first chamber had an air entrance pumped by air compressor, providing constant air flow. The cigarettes were placed and lighted in this first chamber and the air steam enabled the cigarette smoke to reach the second chamber, where the specimens were placed [14]. The second chamber had two connected orifices for refluxing the cigarette smoke, which provided the maximum contact of the cigarette smoke with the specimens. The specimens were exposed to ten cigarettes smoke (Derby. Souza-Cruz. São Paulo. Brazil) for 8 minutes per daily cycle, in a total of 6 cycles. After each daily exposure, the specimens were stored for 24 h at 37ºC and 100% relative humidity. After 30 and 60 cigarettes smoke exposure, a new color and gloss assessments were performed.

Finally, prophylaxis of all specimens with pumice and water paste was performed with a brush (KG Sorensen Ind. E Com. Ltda. São Paulo. Brazil) mounted in low-speed handpiece during 5s. A new color and gloss assessments were performed.

Statistical analysis

The means were evaluated by analysis of variance (two-way repeated ANOVA). The tested variables were type of resin and exposure to cigarette/prophylaxis (repetition variable). The Tukey's test was used for multiple comparisons. The level of significance used was 5%.

RESULTS

Color stability

For color stability, differences among materials, time and between interaction of factors ($p < 0.01$) were detected. The results are presented in Figure 1. According to the ΔE00 values, it can be observed that all samples presented color change, ranging from 0.3 to 4.2, depending on the evaluation period. Resin composites were the least affected by aging, with no statistical difference between both resins ($p = 0.99$). For bis-acryl resins, BisLUX and BisPRO presented color changes similar to the resin composites after prophylaxis ($p > 0.44$). BisVIS and BisYPR presented the worst performance, even after prophylaxis.

Surface gloss stability

Differences among materials, time and between interaction of factors ($p < 0.01$) were detected. The obtained results are displayed in Figure 2. In general, the staining by cigarette smoke

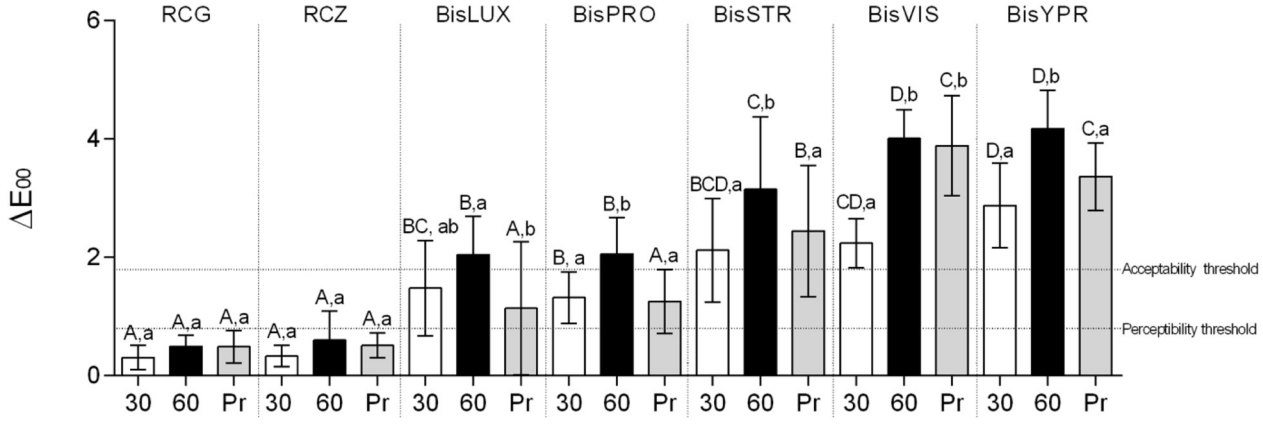

Figure 1 - Color changes (ΔE00) according to the resin tested and the phase of evaluation. The acceptability and perceptibility threshold for color changes are also reported. Footnote: Similar capital letters represent equal results considering each period of evaluation (30, 60 or PR). Small letters represent differences within each type of resin tested.

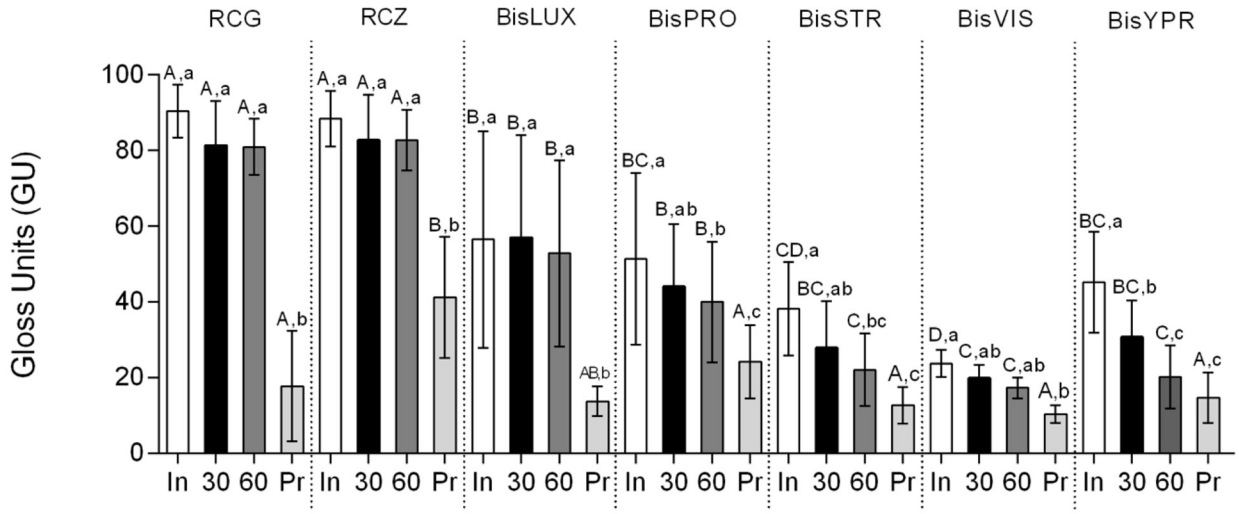

Figure 2 - GU values according to the resin tested and the phase of evaluation. Footnote: Similar capital letters represent equal results considering each period of evaluation (30, 60 or PR). Small letters represent differences within each type of resin tested.

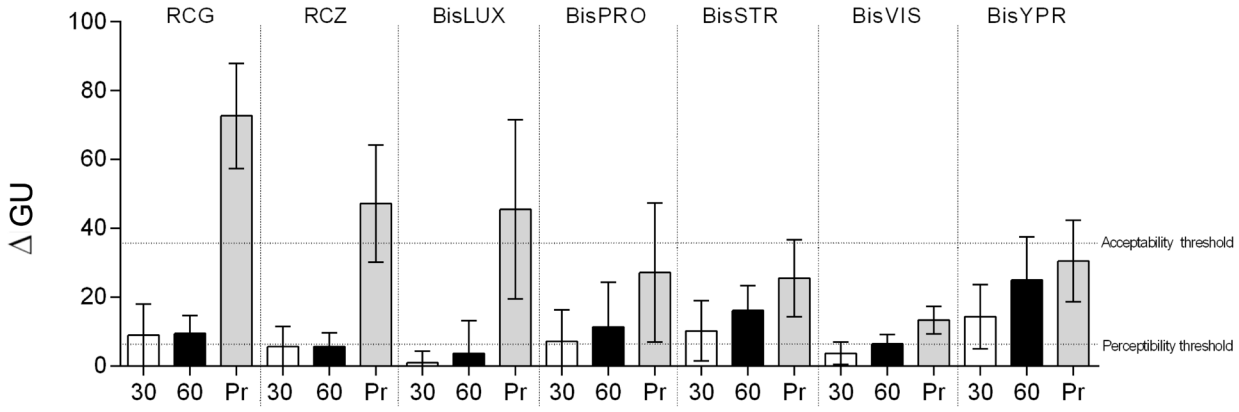

Figure 3 - Gloss variation (ΔGU) for each type of resin and period of assessment are reported. The acceptability and perceptibility threshold for surface gloss alterations are also presented.

did not impact the gloss of the resin composites and BisLUX and BisVIS. BisPRO and BisSTR, showed a reduction in gloss after 60 cigarettes. The gloss of BisYPR presented decreased GU at all evaluated periods. Prophylaxis negatively influenced the surface gloss of most tested materials. The gloss variation, between the baseline and after aging protocols, and also the limits of perceptibility and acceptability can be found in Figure 3. Most of the ΔGU were above the perceptibility level and under the acceptable ranges.

DISCUSSION

The comparison between resin composites and bis-acryl resins might be perceived as inadequate by some readers, especially considering the polishing protocols indicated by their respective manufacturer are different. The bis-acryl resins were brushed with ethanol damped gauze for removing the superficial inhibition layer, while the resin composites were polished with silicon carbide discs. However, that comparison is important to understand the properties of bis-acryl resins considering the level of staining and also have a final restorative material (resin composites) used for anterior direct restorations as a reference.

This study aimed to analyze the effect of cigarette smoke on color and gloss of resin composites and bis-acryl resins. The first null hypothesis was not accepted because there were differences in color and surface gloss for the different types of materials. and the periods evaluated.

It is known that cigarette smoke is an aerosol formed by a gaseous complex and a mixture

of particles with more than 6000 components, being composed by toxic substances such as carbon monoxide and dioxide (present in the gaseous phase), and ammonia, cadmium, lead and predominantly nicotine (present in the particulate phase) [11,12]. Besides the smoke components, nicotine oxidation alone is capable of generating a yellow stain [13]. In this way, the components found in cigarette smoke are capable of causing color changes in restorative materials and acrylic resin [9,10,14-18].

Several studies that evaluated the color stability of resin composites submitted to cigarette smoke exposure, concluded color of materials are altered not only at the surface, considering that, even after prophylaxis or repolishing protocols, the resins did not return to the baseline characteristics [15-18]. The mechanism of how staining occurs is unknown and needs further investigation [18]. However, factors such as the resinous matrix, the surface characteristics and the polishing of the material, possibly influence color stability [18]. These data are consistent with those found in the present study. Although the resin composites performed better than bis-acryl resins, both showed a color change. The comparison with resin composites in the present study is granted as there is reference data in the literature and also due the fact they are more stable and could provide an adequate clinical parameter for the comparisons. There is however, no correlation with the frequency of smoking and restoration staining, thus our study followed other previous reported data for possible comparisons [14].

Considering the prophilaxys, the speed and rotation of polishing discs and brushes might affect the surface properties of resin composites. That characteristic was not measured in our study and should be the focus of future works. Moreover, although that information was not collected, the procedure was performed by the same trained operator simulating clinical conditions, a fact that might have reduced possible variations.

Regarding bis-acryl resins, studies that evaluated their behavior in staining solutions concluded that pigments may be able to penetrate the material through the gaps formed after the setting reaction, since bis-acryl resins have a more heterogeneous composition, which facilitates staining and consequent absorption of pigments [19-21]. However, there are few studies that assess the color stability of this group of resins, including aging by cigarette smoke. Within the group of bis-acryl resins, differences in color stability were found between the resins. If we take into account the perceptibility and acceptability limit, proposed by Paravina et al. [22], in which the human eye is able to perceive color differences from 0.8 and patients would accept variations up to 1.8, resins BisLUX and BisPRO present the best performance, because after the prophylaxis protocol, this group of resins returned to acceptable values, being similar to the values found for resin composites. Also, BisVIS and BisYPR, even after prophylaxis, maintained their $\Delta E00$ values well above the acceptability limit.

The second null hypothesis was not accepted, since there were differences among the evaluated periods. In in vitro studies support that color change after cigarette smoke exposure might happen due to pigment deposition on the surface of materials, or intrinsic impregnation, due to physical-chemical reactions inside the material [15]. In this context, the superficial removal of the pigments was used in order to target the removal of pigment adsorbed on the surface. This abrasion performed was possibly sufficient for this removal, since the gloss values decreased after the prophylaxis protocol (Figure 2 - gloss), confirming the surface abrasion. When evaluating Figure 2, both resin composites had their gloss decreased dramatically after prophylaxis in comparison to the baseline, fact also detected with the BisLUX and BisPRO.

In the present study, the protocol recommended by the manufacturers to remove the inhibition layer of cured bis-acryl resin using ethanol was employed. However, recent studies have shown that the use of abrasive devices in order to polish the surface of the material, improves its surface characteristics [23,24]. A study that evaluated the color stability of a bis-acryl resin submitted to polishing, thermocycling, and immersion in different drinks, concluded that polishing is capable of minimizing the stains caused by aging and the use of dyes [24]. The literature reports that the less polished the surface, the more pigment deposition is observed, as there are more areas for pigment retention and dental biofilm [24,25]. In the present study, BisSTR, BisVIS and BisYPR had the highest color change values and the lowest gloss values, which suggests that the surface possibly had more irregularities and, therefore, greater chances of

retention and pigment incorporation. Thus, we are not aware if the results would be the similar if the samples had been polished.

It is reported that the human eye is able to perceive gloss variations of 6.4 GU and accept a difference of up to 35.7 GU [26]. Thus, when analyzing the gloss data for the resin composites, prophylaxis could generate an esthetic problem for the patient, given that the difference between the initial values and those found after prophylaxis with pumice paste and water, are above considerable acceptable limit (Figure 3) [26]. Regarding bis-acryl group, the low gloss values could also have an unfavorable impact compared to dental enamel. In this context, BisLUX and BisPRO would present the smallest differences in relation to dental enamel and / or a highly polished adjacent resin restoration.

In a clinical scenarios, other factors could influence the staining, such as the presence of saliva, lower contact with smoke, temperature of the oral cavity, among others. Regarding the surface gloss, it is reported that factors such as brushing, ethanol use, light and heat, can also influence the stability of this property [27]. Therefore, clinical studies should be carried out with the objective of evaluating the clinical performance of restorative materials in smoking patients.

CONCLUSION

Through the proposed methodology, we can conclude that:

- Resin composites are less susceptible to staining when compared to bisacrylic resins;
- The resin composites were stained within the limits of perceptibility and acceptability, together with the Luxatemp and Protemp 4 bisacrylic resins after prophylaxis with pumice and water;
- Structor 3, Visalys Temp and Yprov bisacryl had the highest staining value even after prophylaxis with pumice and water;
- Prophylaxis with pumice and water reduced the surface gloss of resins in general.

Authors' Contributions

RSR: conceptualization, experimental design, data collection, and manuscript writing. VR, MYS, FMS: conceptualization, data collection, and manuscript writing. EB: conceptualization and supervision, experimental design, data analysis, and manuscript revision.

Conflict of Interest

The authors declare no conflict of interest.

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Regulatory Statement

The study was conducted in vitro and did not involve human or animal subjects. Thus, no revision from the Institutional Review Board was required.

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