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Effect of finishing and polishing systems on surface roughness and color stability of aesthetic restorations exposed to staining solution.

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ABSTRACT
The color and the surface roughness of aesthetic restorations are related to the clinical sucess and longevity of these treatments. ***Aim:*** *This study evaluated the influence of finishing and polishing systems, and storage media on the surface roughness and color stability of aesthetic restorative composites.* ***Materials and Method:*** *Cylindrical specimens (n=10) were prepared and treated according to: 1. Type of composite resin (nanofilled- Filtek Z350XT, suprananofilled- Estelite Omega, nanohybrid- Empress Direct); 2. Type of finishing and polishing systems (no polishing, aluminum oxide discs or abrasive rubber polishers); and 3. Type of immersion medium (water or coffee, 3 h/day/30 days). Surface roughness (Ra - μm) and color stability (L, ΔEab, and ΔE00) were evaluated at baseline (after polishing) and final time (after immersion). Data were subjected to Kruskal-Wallis, Mann-Whitney, Wilcoxon, and Student-Newman-Keuls tests (α=0.05).* ***Results:*** *Nanohybrid (p<0.001) and suprananofilled composite resins (p=0.004) showed an increase in Ra after polishing, regardless the finishing and polishing system. After immersion in coffee, the nanofilled composite had the highest roughness values (p=0.032). L values increased for all resins after polishing (p<0.05). Suprananofilled composites had the greatest color stability with the lowest values of ΔEab and ΔE00.* ***Conclusions:*** *Finishing and polishing systems had an impact on the surface roughness and color stability of all aesthetic resins, and their effectiveness depended on the type of composite resin.*

Keywords: *composite resins - surface properties - color - acids*

Efeito de sistemas de acabamento e polimento na rugosidade superficial e estabilidade de cor de restaurações estéticas expostas a solução de manchamento.

RESUMO
A cor e a rugosidade de superfície das restaurações estéticas estão relacionadas ao sucesso clínico e manutenção destes tratamentos ao longo do tempo. ***Objetivo:*** *Este estudo avaliou a influência de sistemas de acabamento e polimento e meios de armazenamento na rugosidade superficial e estabilidade de cor de compósitos restauradores de alta estética.* ***Materiais e Método:*** *Foram preparados espécimes cilíndricos de acordo com os fatores em estudo (n=10): 1. Tipo de resina composta (nanoparticulada-Filtek Z350XT, suprananoparticulada- Estelite Omega, nanohíbrida- Empress Direct); 2. Tipo de sistemas de acabamento e polimento (sem polimento, discos de óxido de alumínio ou borrachas abrasivas); e 3. Tipo de meio de imersão (água ou café, 3 h/dia/30 dias). A rugosidade superficial (Ra - μm) e a estabilidade de cor (L, ΔEab e ΔE00) foram avaliadas no início (pós-polimento) e no final (pós-imersão na solução). Os dados foram submetidos aos testes de Kruskal-Wallis, Mann-Whitney, Wilcoxon e Student-Newman-Keuls (α=0,05).* ***Resultados:*** *As resinas compostas nanohíbrida (p<0,001) e suprananoparticulada (p=0,004) apresentaram aumento em Ra pós-polimento, independentemente do sistema de acabamento e polimento. Em relação ao pós-polimento após imersão em café, a composta nanoparticulada mostrou os maiores valores de rugosidade (p=0,032). Os valores de L aumentaram para todas as resinas pós-polimento (p<0,05). A resina suprananoparticulada apresentou a maior estabilidade de cor com os menores valores de ΔEab e ΔE00.* ***Conclusão:*** *Os sistemas de acabamento e polimento tiveram impacto na rugosidade superficial e estabilidade de cor de todos os compósitos estéticos, e sua eficácia depende do tipo de resina composta.*

Palavras-chave: *resinas compostas - propriedades superficiais - cor - ácidos*

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INTRODUCTION

Composite resins consist of an organic polymeric matrix and inorganic fillers bound together by a silane coupling agent[1]. There are several types of composite resins, classified according to filler types and distribution, average filler particle size and polymerization method[2]. Nanocomposites have advantages such as reduced polymerization contraction, improved mechanical properties, enhanced optical behavior, better gloss, improved color stability and reduced wear[3].

To be considered clinically successful, composite resin restorations must have long-lasting and functional qualities, including good marginal adaptation, radiopacity, high wear resistance, ease of application, and resistance to degradation from contact with water and/or other solvents. However, despite improvements in the physical properties of composite resins, they are still subject to degradation in the oral cavity[4].

Composite resins provide acceptable aesthetic results due to their superior optical and mechanical properties[5] and can be used for veneers. Compared to ceramic veneers, composite resin veneers have advantages such as adhesion between the composite resin and the dental substrate, low cost, and shorter clinical manufacturing time. Restoration failure behavior differs between anterior and posterior teeth, and although anterior restorations have fewer secondary caries lesions, they are more often replaced for reasons such as aesthetic appearance and staining[6]. Color stability is thus crucial to aesthetic restorations and has direct impact on the clinical success of restorative procedures[7], so it is important to consider that the conditions to which restorative materials are exposed can influence their chemical degradation.

Another important factor for the success of restorations is surface roughness. The surface roughness of composite resins can be minimized by employing an effective finishing and polishing protocol[8]. A variety of instruments are used for finishing and polishing, including carbide finishing burs, diamond finishing burs, abrasive-impregnated rubber cups and tips, aluminum oxide-coated abrasive discs, abrasive strips, and abrasive pastes. The effectiveness of finishing and polishing systems depends on the substrate, type of abrasive used, time spent with each abrasive, pressure applied, alignment of abrasive surfaces and geometry of abrasive instruments, presence or absence of lubrication, and immediate or delayed timing of polishing after composite resin polymerization[9,10]. Several finishing and polishing systems are available for composite resins. These systems may involve one or several steps and vary significantly in composition, presentation, and the type and hardness of abrasive particles[11].

However, there is limited information in the literature regarding polishing protocols for composite resins with high aesthetic performance. Therefore, the aim of this study was to evaluate the influence of finishing and polishing systems on the surface roughness and color stability of composite resins recommended for high aesthetic performance in anterior teeth, as a result of exposure to chemical challenges. The first null hypothesis was that the finishing and polishing systems would not significantly impact surface roughness of composite resins with high aesthetic performance when they were exposed to coffee. The second null hypothesis was that the finishing and polishing systems would not significantly impact color stability of composite resins with high aesthetic performance when they were exposed to coffee.

MATERIALS AND METHOD

The factors in the study were: 1) Type of composite resin material (Nanofilled, Suprananofilled, Nanohybrid); 2) Type of finishing and polishing systems (no polishing, aluminum oxide discs, abrasive rubber); and 3) Type of immersion medium (water, coffee). The surface roughness (Ra) and color stability (L, ΔEab, ΔE00) performance of the composites were measured at baseline (after polishing) and final time (after immersion).

Sixty cylindrical specimens (n=10 per treatment) of each composite resin (described in Table 1) were manufactured using a rubber mold 2 mm tall and 5 mm in diameter, positioned on a glass plate and polyester strip. The composite resins were inserted in a single increment into the mold, and another polyester strip and glass plate were placed on top for 15 s under a weight of 500 g. The cylinders were photoactivated according to the manufacturer's instructions for 20 s using a LED device at Standard power (Valo, Ultradent, South Jordan, Utah, USA) with a light intensity of 1000 mW/cm^2. The distance between the light source and the specimens was

Table 1. Manufacturer and composition of the composite resins used in this study.

Manufacturer	Composition	
	Matrix	Filler
Filtek Z350 XT 3M (Sumaré, SP, Brazil)	Bis-GMA Bis-EMA UDMA TEGDMA	Nanofilled - Silica: 20 nm (non-agglomerated) - Zirconia: 4-11 nm (unbonded) - Zirconia/silica agglomerates: 4-11 µm - Inorganic particles: 72.5% by weight
Estelite Omega Tokuyama (Encinitas, CA, USA)	Bis-GMA TEGDMA	Suprananofilled - SiO^2-ZrO^2 spherical particles: 200 nm - Inorganic particles: 82% by weight
Empress Direct Ivoclar (Barueri, SP, Brazil)	Bis-GMA UDMA	Nanohybrid - Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide and copolymer: from 40 nm to 3000 nm (average size = 550 nm). - Inorganic particles: 75-79% by weight

Bis GMA – Bisphenol A glycidyl methacrylate; UDMA - Urethane dimethacrylate; TEGDMA – Triethylene glycol dimethacrylate; Bis-EMA - Bisphenol A glycidyl dimethacrylate ethoxylate.

standardized by the polyester strip. The specimens were placed on cotton moistened with distilled water and stored in a humid environment in a refrigerator. Each specimen was lightly engraved with a number using a high-speed spherical diamond tip (No. 3072, KG Sorensen, Cotia, SP, Brazil) on the surface opposite the testing surface, to ensure that tests were applied and read in a standardized manner on the same face.

For the finishing and polishing procedures, the specimens were divided into three groups, as follows: **1.** Polyester matrix – without finishing and polishing (control group); **2.** Multi-step aluminum oxide discs and diamond paste with polishing felt - medium (40 µm), fine (24 µm), extra fine (8 µm) (SofLex, 3M, Sumaré, SP, Brazil); **3.** Multi-step bullet-shaped abrasive silicone rubber tips impregnated with silicon carbide and aluminum oxide particles, and diamond paste with polishing felt - Coarse/green (40 µm); medium/yellow (30 µm), fine/white (5 µm) (Jiffy, Ultradent, South Jordan, UT, USA), associated with diamond polish - diamond particles in an aqueous base grain size (0.5 µm) (Ultradent, South Jordan, UT, USA).

A base was made of heavy addition silicone paste (Yller, Pelotas, RS, Brazil). Before the silicone was completely set, three test objects were inserted to form recesses to hold the resin blocks. The resin blocks were allowed to fully set within the heavy silicone. All the specimens were polished on this base, with each specimen placed in a recess with the end to be polished facing upwards. Each polishing system was applied to 20 specimens of each resin for 20 s with gentle pressure in the same direction, approximately 25 movements on each specimen at controlled speed of 7,500 rpm[12]. Between the use of each system (felt), the specimen was washed with air and water spray for 10 s with a triple syringe to remove debris. The polishing systems (felts) were used with polishing paste under the same pressure and time conditions. Abrasive rubber tips were discarded after every 3 specimens, while aluminum oxide discs and polishing felt discs with diamond paste were only used once.

The immersion protocol followed that of a previous study[13]. Thirty specimens of each type of composite resin (10 from each of groups 1. 2 and 3) were immersed in either: 1) Distilled water - Chemically pure, free of soluble salts (AM distributor, São Paulo, SP, Brazil) (pH = 6.0); or 2) Coffee made from traditional ground roasted coffee beans (Café Três Corações S.A., Três Corações, MG, Brazil) (pH = 5.39, using MS Tecnopon (Model MPA210, Piracicaba, SP, Brazil). Coffee was prepared by heating water (± 85ºC) for 5 minutes in a microwave (power 100 W), and then pouring it through a plastic strainer lined with a paper filter containing ground coffee beans (water/ground coffee ratio = 700 mL/58 g).

For 30 consecutive days, specimens were immersed in 5 mL of coffee or distilled water at room temperature for 3 hours, and then stored in a humid environment under refrigeration. Fresh distilled water and coffee were used every day.

Average surface roughness (Ra) was evaluated for each specimen at baseline (after polishing) and final time (after immersion in water or coffee), using a profilometer (Mitutoyo, Suzano, SP, Brazil). Sampling length was 2.4 mm, made up of three 0.8 mm cut-offs taken sequentially in horizontal, vertical and oblique directions at a stylus speed of 0.25 mm/s.

Color was evaluated at baseline (after initial polishing) and final time (after immersion in distilled water or coffee). Before color evaluation, the specimens were washed with distilled water for 60 s and dried with absorbent paper. Color was analyzed with a colorimetry spectrophotometer, CIEl*a*b* system (VITA Easyshade Advance 4.0 - VITA Zahnfabrik, Bad Säckingen, Germany). Briefly, a box with a white background was used to avoid the influence of external light on color measurement. The color was evaluated by three readings on each specimen, with the result being the average of the three values (L*). Regarding the color change parameter (ΔEab), the range to be used to distinguish changes in color values was ΔEab > 1.2. Thus, values greater than 1.2 were considered to be easily observable and clinical changes. This threshold is in line with previous criteria[14], that deem values above 1.2 as not acceptable. In the ΔE00 formula, ΔL* represents the variation of the L* coordinate indicating lightness (black-white axis); ΔC represents the difference in saturation (chromacity); ΔH represents differences in hue; eRT is a function that considers the interaction between chromacity and hue differences in a blue region of the spectrum. The ΔE00 values were calculated sequentially.

$$\Delta E00 = \sqrt{(\Delta L'/kLSL)2 + (\Delta C'/kCSC)2 + (\Delta H'/kHSH)2 + RT(\Delta C'/kCSC)(\Delta H'/(kHSh)}$$

Statistical analysis

As the data did not meet normal distribution and homogeneity of variance, the surface roughness and color (L, ΔEab and ΔE00) of the composite resins subjected to finishing and polishing systems and immersion solutions were analyzed using the Kruskal-Wallis, Mann-Whitney and Wilcoxon tests. Student-Newman-Keuls tests were used for multiple comparisons. Statistical calculations were performed using SPSS 23 (SPSS Inc., Chicago, IL, USA) and BioEstat 5.0 (Fundação Mamirauá, Belém, PA, Brazil) (α=0.05).

RESULTS

Table 2 shows the means and standard deviations of surface roughness (Ra - µm) for the different types of composite resins, according to the finishing and polishing systems and type of immersion medium. For Estelite Omega (suprananofilled, p=0.004) and Empress Direct (nanohybrid, p<0.001), roughness was higher after finishing and polishing than without polishing (using only polyester strip – control group), regardless of the system used. For Filtek

Table 2. Mean (SD) of surface roughness (µm) of the different types of composite resins according to the finishing and polishing system and the immersion medium.

Experimental Groups		Control (without polishing)	Discs + felts	Rubbers + felts
Filtek Z350 XT (Nanofilled)				
Baseline (post-polishing)		0.276 (0.117) **A**	0.313(0.104) **A**	0.339(0.123) **A**
Final	Water (post-immersion)	0.381 (0.221) **a**	0.416(0.153) **a**	0.457(0.242) ***a**
	Coffee (post-immersion)	0.425 (0.209) ***a**	0.449(0.118) ***a**	0.385(0.186) ***a**
Estelite Omega (Suprananofilled)				
Baseline (post-polishing)		0.306(0.143) **A**	0.416(0.153) **B**	0.464(0.144) **B**
Final	Water (post-immersion)	0.223(0.085) **a**	0.467(0.149) **a**	0.665(0.253) **a**
	Coffee (post-immersion)	0.254(0.143) **a**	0.576(0.251) **a**	0.521(0.155) **a**
Empress Direct (Nanohybrid)				
Baseline (post-polishing)		0.185 (0.114) **A**	0.317 (0.094) **B**	0.385 (0.093) **B**
Final	Water (post-immersion)	0.139 (0.054) **a**	0.325 (0.137) **a**	0.431 (0.103) **a**
	Coffee (post-immersion)	0.237 (0.141) **a**	0.267 (0.090) **a**	0.433 (0.126) **a**

Different capital letters indicate a significant difference between finishing and polishing systems by Kruskal-Wallis and Student-Newman-Keuls tests.
* indicates significant difference in relation to the post-polishing value by Mann-Whitney. Equal lowercase letters indicate no significant difference between specimens immersed in distilled water or coffee by Mann-Whitney.

Z350 XT (nanofilled), there was no statistically significant difference with finishing and polishing or without (using only polyester strip – control group ($p=0.269$). However, Filtek Z350 XT had the highest roughness values after polishing and immersion in coffee ($p=0.032$, Table 2). For all other groups, there was no significant difference in the values after finishing and polishing and after immersion ($p>0.05$).

The L values (lightness) for all composite resins were significantly affected by finishing and polishing systems and by immersion (Table 3). The lowest L value was observed for the control group (without polishing) after immersion in coffee ($p<0.001$). At baseline, Estelite Omega (suprananofilled) and Empress direct (nanohybrid) had the highest L values when multi-step aluminum discs and felts were used as finishing and polishing system ($p<0.001$), while for Filtek Z350 XT (nanofilled), there was no significant difference between the finishing and polishing systems ($p>0.05$).

Table 4 shows that the values of ΔEab ($p<0.001$) and ΔE00 ($p<0.002$) were significantly higher after immersion in coffee than in distilled water, regardless of the type of composite resin. Specifically, Empress Direct (nanohybrid) immersed in coffee had the lowest ΔEab ($p=0.009$) and ΔE00 ($p=0.010$) values when polished with multi-step aluminum oxide discs + felt disc + paste. Estelite Omega (suprananofilled) ($p=0.002$) had significantly lower ΔEab and ΔE00 than nanofilled and nanohybrid composite resins, which did not differ significantly from each other. For these two indicators, the color change was significantly greater in the absence of finishing and polishing.

In distilled water, only Estelite Omega (suprananofilled) showed no statistically significant differences for ΔEab ($p=0.168$) and ΔE00 ($p=0.374$) values considering the finishing and polishing systems. Filtek Z350 XT (nanofilled) had lower ΔEab ($p=0.003$) and ΔE00 ($p=0.004$) when aluminum disc + felts were used. For Empress Direct (nanohybrid), the ΔEab ($p=0.005$) and ΔE00 ($p=0.002$) values were significantly higher in the group without polishing than in the group polished with aluminum oxide discs + felt + paste, while the group polished with abrasive rubber had the lowest ΔEab and ΔE00 values.

DISCUSSION

The first null hypothesis – that finishing and polishing systems would not significantly impact the surface roughness of composite resins with high aesthetic performance when they were subjected to a chemical challenge – was rejected. After being treated with finishing and polishing systems, Estelite Omega (suprananofilled) and Empress Direct (nanohybrid) had higher roughness values

Table 3. Means (SD) of color parameters L for composite resins, according to the finishing and polishing system and immersion medium.

Experimental Groups		Control (without polishing)	Discs + felts	Rubbers + felts
	Filtek Z350 XT (Nanofilled)			
	Baseline (post-polishing)	84.6 (1.6) B	87.9 (1.8) A	86.1 (1.1) A
Final	Water (post-immersion)	81.9 (1.0) *a	84.7 (1.1) *a	84.1 (1.3) *a
	Coffee (post-immersion)	70.0 (2.3) *b	75.6 (1.4) *b	73.8 (1.7) *b
	Estelite Omega (Suprananofilled)			
	Baseline (post-polishing)	85.0 (1.9) C	88.9 (1.8) A	86.8 (1.3) B
Final	Water (post-immersion)	84.9 (1.3) a	87.5 (1.5) *a	86.7 (1.4) a
	Coffee (post-immersion)	74.0 (0.6) *b	76.8 (1.2) *b	77.3 (1.4) *b
	Empress Direct (Nanohybrid)			
	Baseline (post-polishing)	85.4 (1.4) B	88.1 (1.1) A	86.3 (1.4) B
Final	Water (post-immersion)	82.4 (1.4) *a	85.1 (0.8) *a	83.5 (0.6) *a
	Coffee (post-immersion)	68.2 (1.6) *b	73.2 (1.7) *b	70.5 (1.7) *b

Different capital letters indicate an intragroup (in line) significant difference by Kruskal-Wallis and Wilcoxon tests. Different lowercase letters indicate a significant difference between immersion media by Mann-Whitney. * indicates significant difference in relation to the post-polishing value by Mann-Whitney.

Table 4. Means (SD) of ΔEab and ΔE00 for composite resins according to the finishing and polishing system and the immersion medium.

	Experimental Groups	Control (without polishing)	Discs + felts	Rubbers + felts
ΔEab	*Filtek Z350 XT (Nanofilled)*			
	Water (post-immersion)	3.40 (0.74) A**b	2.23 (0.55) B*b	2.94 (0.57) A**b
	Coffee (post-immersion)	16.94 (4.22) A$^{\#\#}$a	14.34 (3.23) AB$^{\#}$a	13.20 (1.64) B$^{\#}$a
	Estelite Omega (Suprananofilled)			
	Water (post-immersion)	1.99 (0.50) A*b	1.92 (0.87) A*b	1.61 (0.31) A*b
	Coffee (post-immersion)	14.28 (1.13) A$^{\#}$a	14.06 (1.22) A$^{\#}$a	11.93 (1.10) B$^{\#}$a
	Empress Direct (Nanohybrid)			
	Water (post-immersion)	3.75 (1.13) A**b	3.65 (0.77) A**b	2.39 (0.68) B**b
	Coffee (post-immersion)	18.25 (1.64) A$^{\#\#}$a	15.17 (1.91) B$^{\#}$a	17.31 (1.88) AB$^{\#\#}$a
ΔE00	*Filtek Z350 XT (Nanofilled)*			
	Water (post-immersion)	2.35 (0.47) A**b	1.64 (0.34) B*b	2.09 (0.36) A**b
	Coffee (post-immersion)	12.15 (2.78) A$^{\#\#}$a	10.38 (2.36) A$^{\#}$a	9.82 (1.21) A$^{\#\#}$a
	Estelite Omega (Suprananofilled)			
	Water (post-immersion)	84.9 (1.3) a	87.5 (1.5) *a	86.7 (1.4) a
	Coffee (post-immersion)	74.0 (0.6) *b	76.8 (1.2) *b	77.3 (1.4) *b
	Empress Direct (Nanohybrid)			
	Water (post-immersion)	2.39 (0.60) A**b	2.44 (0.41) A**b	1.68 (0.30) B**b
	Coffee (post-immersion)	12.96 (1.27) A$^{\#\#}$a	10.75 (1.36) B$^{\#}$a	12.31 (1.39) A$^{\#\#\#}$a

Different capital letters indicate significant differences between finishing and polishing systems by Kruskal-Wallis and Student-Newman-Keuls tests ($p<0.05$). Different lowercase letters indicate intragroup significant difference immersed in distilled water or coffee by Kruskal-Wallis and Student-Newman-Keuls tests ($p<0.001$). * indicates significant difference among the type of finishing and polishing immersed in water by Kruskal-Wallis and Wilcoxon tests. ** indicates significant difference among composite resins immersed in water, considering each system separately by Mann-Whitney and Wilcoxon tests. # indicates significant difference among composite resins immersed in coffee, considering each finishing and polishing system separately by Mann-Whitney and Wilcoxon tests.

than when not polished (using only polyester strip – control group), regardless of the type of system used. This agrees with another study reporting that the smoothest surfaces were observed for the polyester strip (control group) [15]. The smooth surface formed by the matrix tends to be rich in the organic matrix and free of any compounds that are inhibited by air[15]. However, the removal of the outermost composite layer by finishing and polishing procedures is necessary to produce a harder, wear-resistant, color-stable restoration[16]. In addition, most aesthetic restorations require the removal of excess material and refinement in anatomy, thus necessitating the use of finishing and polishing systems. However, these treatments can produce variability in the degree of roughness as well as the removal of the resin oxygen-inhibited layer[17].

In the present study, no difference was found for Filtek Z350 XT (nanofilled resin) between the groups with finishing and polishing or without (only polyester strip). This may be explained by the size of the inorganic particles present in the composite resin. The larger the size of the particles lost during abrasion, the greater the increase in roughness[18]. Thus, Filtek Z350 XT, a nanofilled resin with particles from 4 to 20 nm, was developed to combine high polishing and gloss retention[19]. When composites with nanoclusters undergo an abrasive process, individual nanometric primary particles may be lost[18]. Hence, the surfaces resulting from wear have smaller defects and better gloss retention when compared to microhybrid compounds that lose larger secondary particles, leading to greater defects on the surface and increased roughness. This difference explains the performance of the Filtek Z350 XT (nanofilled) resin, which exhibits less change in surface roughness after finishing and polishing.

However, after immersing Filtek Z350 XT specimens in water or coffee, the specimens polished with aluminum oxide discs had greater surface roughness than and those subjected to the sequential use of rubber tips plus felt with diamond paste. This could be explained by the degradation or dissolution of the polymerized organic matrix when exposed to water[19]. The water absorption of the polymeric compound is highly dependent on the chemical structure of the resin monomers[20]. The phenomenon of sorption in composites is a diffusion-controlled process that results in chemical degradation, caused by the release of residual monomer and detachment between the matrix and the filler[21]. A study on the solubility and discoloration of monomers in composites reported that, in terms of absorption, solubility and color change, the monomers were ranked as BisEMA <UDMA<BisGMA[22]. Furthermore, studies indicate that TEGDMA is the monomer that causes the most substantial colour alteration[23]. Specifically, Filtek Z350 XT (nanofilled), whose roughness increased after immersion in water and coffee, contains all four types of monomers in its composition. This may have caused the release of residual monomers and subsequent detachment of fillers, leading to an increase in surface roughness. Despite the lower average pH of coffee (5.39) compared to water (6.0), no significant difference in surface roughness values was observed between specimens according to whether they were immersed in water or coffee. Coffee was selected as the coloring solution for this study due to its rich content of chromogenic substances such as tannin and chlorogenic acid, compared to other beverages[34]. However, the presence of chlorogenic acid in it was not deemed relevant for inducing greater hydrolytic degradation in specimens immersed in coffee.

Although the results of the present research demonstrated that the effect of the polishing system on surface roughness was material-dependent, the literature reports that the lowest Ra values on the surface of composite resins are generally provided by aluminum oxide discs[12]. According to a systematic review, aluminum oxide was one of the most important components for achieving a smooth surface because it is harder than the filler particles in composite resins[19]. Otherwise, the polishing agent would only remove the soft composite resin matrix, leaving protruding filler particles on the surface[24].

In the current study, both polishing systems increased the surface roughness of the specimens to values greater than 0.2 µm, which would lead to the accumulation of biofilm on the restoration and could result in gingival inflammation, surface stains and secondary cavities[25]. Biofilm retention depends on several factors, not just surface roughness, and the surface of polished restorations must have a maximum roughness of 0.50 µm in order not to be perceptible to the patient[26]. Filtek Z350 XT (nanofilled) and Empress Direct (nanohybrid) resins achieved Ra values lower than this threshold, while Estelite Omega (suprananofilled) obtained comparable values when polished both with discs and with rubber tips. The finishing and polishing systems contributed noticeable smoothness.

Considering color stability, the null hypothesis – that the finishing and polishing systems would not significantly impact the color stability of composite resins with high aesthetic performance when subjected to chemical challenge - was rejected. Overall, the L parameter decreased after immersion in water or coffee, as expected for Estelite Omega resin (suprananofilled) immersed in water. The absorption of water or pigment leads to degradation of the organic matrix, as described above, and consequently a decrease in brightness. Increased water absorption results in low color stability due to the increase in the free volume of the polymer formed and greater space for water molecules to diffuse into the polymer network, thus contributing first to its degradation and then to discoloration[20]. Furthermore, color and light reflection are negatively affected by a rough surface. The lower the optical reflection, the rougher is the surface[27]. Thus, the lightness of the control group of Estelite Omega (suprananofilled), which did not undergo any type of finishing or polishing and, therefore, maintained the smoothness of the polyester strip, was not affected by immersion in water.

Considering the finishing and polishing systems, the use of multi-step aluminum oxide discs increased the L values for the Empress Direct (nanohybrid) and Estelite Omega (suprananofilled) resins. Some authors have reported that when surface roughness increases, the degree of random light reflection will increase, resulting in a decrease in brightness[27-29]. For the Filtek Z350 XT (nanofilled) resin immersed in both water and coffee, the highest ΔEab and $\Delta E00$ were observed in the rubber-polished specimens. In Empress Direct (nanohybrid) resins immersed in water, the highest values of ΔEab and $\Delta E00$ were in specimens polished with aluminum oxide discs.

However, in specimens immersed in coffee, there was no difference between polishing with rubber or aluminum discs. Given that the composition of the resin influences its optical properties, materials containing different types of monomers may present differences in color and translucency[30]. Polishing and finishing systems influence color, but this influence is material-dependent. The performance of the two tested finishing and polishing systems differed according to the resin used, making it impossible to conclude that one system, whether disc or rubber, outperforms the other. A single polishing system does not uniformly achieve the same surface quality for all composite resins. This variability is attributable not only to the quality of the polishes, but also to the interaction between the polisher and the composite resin[11].

Furthermore, there are additional considerations regarding the composition of the Empress (nanohybrid) and Estelite (suprananofilled) resins that may elucidate the results obtained in this study. One notable aspect is related to the quality of inorganic fillers. Modified strontium glass, present in Empress Direct, is known to match the index of refraction of the UDMA resin matrix, offering improved aesthetics. In contrast, composites with barium glass, commonly found in some materials, have a higher index of refraction than UDMA resin, resulting in reduced translucency and inferior aesthetics[31]. Additionally, composites with pure silica or quartz fillers tend to be more inert in water, while those containing radiopaque glasses may undergo greater dissolution in water and saline solutions[32]. Empress Direct (nanohybrid) resin, tested in this study, contains barium glass, which may explain its less stable performance in terms of color evaluation compared to Estelite Omega (suprananofilled), which contains silica and zirconia. Another crucial factor is the organic matrix. Estelite (suprananofilled) resin contains the TEGDMA monomer as a diluent. The presence of TEGDMA can enhance surface hardness, elastic modulus, and the degree of polymerization compared to BisEMA, which is present in Empress Direct (nanohybrid) resin. These factors collectively contribute to Estelite's superior resistance against coloring agents[33].

There are two main thresholds for evaluating color differences: the perceptibility threshold and the acceptability threshold[14]. These thresholds differ significantly, with reference values for the perceptibility threshold of ΔEab set at 1.2, and the acceptability threshold at 2.7[14]. For ΔE00, the perceptibility threshold is 0.8, and the acceptability threshold is 1.814. In this study, the Estelite Omega composite resin (suprananofilled), after being polished and immersed in water for all groups, maintained acceptability ΔEab values below 2.7 but presented perceptibility values above 1.2. In other words, although the changes were noticeable to the human eye, they were considered acceptable. The other resins in the study exhibited perceptibility and acceptability values above the reference thresholds.

Other authors have reported that among the composites finished with different systems and immersed in various coloring solutions (coffee, red wine, glue), the surfaces that showed the greatest color change were observed in the groups treated with the polyester strip[28]. They suggest that the surface layer, where the organic matrix is predominant, should be removed to have less influence on color stability. Similarly, in the current study, the unpolished control groups finished with the polyester strip achieved the highest values of ΔEab and ΔE00 after immersion in coffee, indicating greater color change.

CONCLUSION

It can be concluded that the finishing and polishing systems had an impact on the surface roughness and color stability of all composite resins with high aesthetic performance, and their effectiveness differed according to the type of composite resin. Estelite Omega (suprananofilled) demonstrated the highest color stability after immersion in either water or coffee, while Filtek Z350 XT (nanofilled) resin surface roughness increased after immersion in water or coffee.

DECLARATION OF CONFLICTING INTERESTS

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