Original Article

Efficacy of Polishing Kits on the Surface Roughness and Color Stability of Different Composite Resins

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Abstract

Objective: Different polishing kits may have different effects on the composite resin surfaces. The aim of this study was to evaluate the surface roughness and color stability of four different composites which was applied different polishing technique. **Materials and Methods:** Thirty specimens were made for each composite resin group (nanohybrid, GrandioSo-GS; nanohybrid, Clearfil Majesty Esthetic-CME; hybrid, Valux Plus-VP; micro-hybrid, Ruby Comp-RC; [15 mm in diameter and 2 mm height]), with the different monomer composition and particle size from a total of 120 specimens. Each composite group was divided into three subgroups (n = 10). The first subgroup of the each composite subgroups served as control (C) and had no surface treatment. The second subgroup of the each composite resin groups was polished with finishing discs (Bisco Finishing Discs; Bisco Inc., Schaumburg, IL, USA). The third subgroup of the each composite resin was polished with polishing wheel (Enhance and PoGo, Dentsply, Konstanz, Germany). The surface roughness and the color differences measurement of the specimens were made and recorded. The data were compared using Kruskal–Wallis test, and regression analysis was used in order to examine the correlation between surface roughness and color differences of the specimens ($\alpha = 0.05$). **Results:** The Kruskal–Wallis test indicated significant difference among the composite resins in terms of ΔE ($P < 0.05$), and there was no statistically significant difference among composite resins in terms of surface roughness ($P > 0.05$). Result of the regression analysis indicated statistically significant correlation between Ra and ΔE values ($P < 0.05$, $r^2 = 0.74$). **Conclusion:** The findings of the present study have clinical relevance in the choice of polishing kits used.

Keywords: *Atomic force microscope, color difference, color stability, composite resin, surface roughness*

Introduction

Increases in patients' esthetic expectations have led dentists to increasingly use composite resin materials for the direct and indirect restoration of teeth.[1,2] However, studies have showed that these materials present color alterations over time.[3,4] The optical properties of the restorative materials are affected by finishing and polishing procedures, and discoloration may occur in these materials in the long term because of intrinsic or extrinsic reasons.[5] Color changes of composite resins may cause both patient and clinician dissatisfaction while the success of an esthetic restoration depends on the color stability of the materials used. The degree of color change can be affected by surface roughness,[6] and when the resin composite is against a Mylar matrix, the smoothest surface is achieved without finishing or polishing.[7] This surface has a resin-rich layer and poor mechanical properties and should be removed; therefore, discoloration of the composite resin may be eliminated.[8] The

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longevity of the composite resin restorations is greatly affected by the quality of the finishing and polishing procedures.[9] Smooth surfaces reduce plaque retention, gingival irritation, recurrent caries, and discoloration of the restoration.[10-12] For oral health considerations, it is also important to determine the best finishing/polishing technique to obtain the best results.[13] For these reasons, finishing and polishing procedures of the composite resins are crucial in dental practice.

Several classification systems have been available for composite resin materials, according to the filler type, the particle size of the filler, and filler distribution. At present, classifications according to particle size have been widely used.[14] de Moraes *et al*.[15] showed that nanohybrid and nanofilled composite resins have approximately equal performance in terms of clinical experience, and their performance is better than that of micro-hybrids.

There are several finishing and polishing materials available in dentistry today such as diamond burs, carbide finishing burs, hard-bonded/surface-coated ceramic diamond rotary instruments, aluminum oxide-impregnated rubber or silicon discs, and wheels.[16]

The aim of the present study was to evaluate the effects of two polishing systems on the surface roughness and color stability of composite resins. The first null hypothesis was that there was no difference between polishing systems in terms of surface roughness and color stability. The second null hypothesis was that there was no difference among the composite resins in terms of surface roughness and color stability. Finally, the third null hypothesis was that there was no correlation between the surface roughness and color stability of the composite resins.

Materials and Methods

Preparation of the specimens

Four light-polymerized composite resins (Shade A3) were used: Two nanohybrids (GrandioSo [GS; Voco GmbH, Cuxhaven, Germany], Clearfil Majesty™ Esthetic [CME; Kuraray Co., Osaka, Japan]), one hybrid (Valux™ Plus [VP; 3M Espe, St. Paul, USA]), and one micro-hybrid (Ruby Comp [RC; Rubydent, Istanbul, Turkey]). In addition, an aluminum oxide/diamond-abrasive-impregnated two step polishing system (Enhance® and PoGo® [EP; Dentsply DeTrey GmbH, Konstanz, Germany]) and aluminum oxide impregnated four step polishing system (Bisco Finishing Discs [BFD]; Bisco Inc., Schaumburg IL, USA) were tested. The properties of the composite resins and the composition of the polishing systems are shown in Tables 1 and 2.

Disc-shaped specimens were prepared using a special cylindrical mold (15 mm in diameter by 2 mm height) and a Mylar strip band. Each material was inserted into the mold and pressed between the Mylar strip band and a glass slide in order to extrude excess material and to produce a smooth surface [Figure 1a and b]. The specimens were polymerized using a halogen curing unit (Optilux 501, Kerr, Orange, CA, USA) according to the manufacturer's instructions, with a light intensity of 500 mW/cm^2 for 40 s. The lamp output of the light was controlled periodically using a radiometer (Hilux, Benlioğlu Dental, Ankara, Turkey) to ensure a light intensity at least 500 mW/cm^2. A total of 120 specimens were prepared from 4 different composite resin groups, where each composite resin group was divided into three subgroups (n = 10): (1) Control group (C), (2) EP group, and (3) BFD group. After that, all specimens were stored in distilled water at 37°C for 24 h. Then, the specimens were polished by a single operator, according to the manufacturer's instructions.

In the control groups, no surface treatment was performed. In the EP group, the specimens were primarily wet-polished for 20 s with enhance at 20,000 rpm, rinsed with water in order to remove debris, and then dried with oil-free air. The polishing protocol was performed with light pressure to achieve smooth surfaces. The specimens were then wet-polished with PoGo at 20,000 rpm, according to the manufacturer's instructions for 40 s, rinsed with water, and then air-dried. In the BFD group, the specimens were wet-polished according to the manufacturer's instructions for 20 s at 20,000 rpm by using polishing discs which were in four grits (Coarse [Brown], Medium [Green], Fine [Blue], and Ultrafine [Tan], respectively). The specimens were then rinsed with water and air-dried. Each polishing material was used only once, and the same low-speed handpiece (Synea Straight; W and H Dentalwerk Bürmoos GmbH, Bürmoos, Austria) was used throughout this study.

Surface roughness measurement

The surface roughness values of each specimen were then measured by using a profilometer (Surftest SJ-301; Mitutoyo America Corporation, Aurora, ABD). For each specimen, five measurements at different locations, with a cut-off length of 25 µm and 2 mm tracing length, and the average values were recorded (R_a; µm).

Color change measurement

First, color surveying of all specimens was performed with a colorimeter device (CR-400; Minolta, Osaka, Japan) using the Commission Internationale de l'Eclairage (CIE) L*a*b* system. The CIE-Lab is expressed by the L*, a*, and b* coordinates, and for each specimen, the color measurement was calculated

3 times, and the average values of L_1*, a_1*, and b_1* were obtained. L* refers to lightness and coordinates with value ranges from black to white. The values of a* and b* are chromaticity that coordinate in the red-green axis and the yellow-blue axis. Following the first color measurements, all specimens were stored in a coffee solution (Nescafe Classic; Nestle, Vevey, Switzerland) at 37°C for 48 h. The coffee (3.6 g) was dissolved in 300 mL of boiling distilled water, and after stirring for 10 min, the solution was filtered through a filter paper. After 48 h of storing the specimens in the coffee solution, they were rinsed with distilled water for 5 min and then blotted with dry tissue paper before color measurements were taken.[1] The second color surveying of all specimens was then measured 3 times, and the average values of L_2*, a_2*, and b_2 were obtained. The total color difference (ΔE*) between the two color measurements was calculated as follows:

$$\Delta E^* = ([L^*_1 - L^*_2]^2 + [a^*_1 - a^*_2]^2 + [b^*_1 - b^*_2]^2)^{½}$$

After color measurement, two specimens were randomly selected from each group for scanning electron microscope (SEM) and atomic force microscope (AFM) analyses.

Statistical analysis

A Kruskal–Wallis test was used to evaluate the color stability and surface roughness data (α = 0.05) using statistical software (SPSS version 20; SPSS Inc., Chicago, IL, USA). Regression analyses were used to examine the correlation between the surface roughness and color differences (α = 0.05).

Results

Evaluation of color stability

Evaluation of color stability among the composite resins

The color difference values of the composite resins are shown in Table 3. The Kruskal–Wallis test indicated significant differences among the composite resins ($P < 0.05$); the highest color difference values were in the VP group, and the lowest were in the CME group.

Evaluation of color stability between the polishing materials

The color difference values of the polishing systems are shown in Table 4. A statistically significant difference was found among the sub-groups ($P < 0.05$); and although there was no significant difference between the EP and BFD polishing systems, the C group showed the highest ΔE values.

Although there was a significant difference between the EP and BFD polishing systems in the GS group ($P < 0.05$), there was no difference in the CME, VP, and RC groups ($P > 0.05$).

Evaluation of surface roughness

Evaluation of surface roughness among composite resins

The surface roughness values are shown in Table 5. There was no statistically significant difference among composite resins ($P > 0.05$).

Evaluation of surface roughness between the polishing systems

The surface roughness values are shown in Table 6. A statistically significant difference was found between the polishing systems ($P < 0.05$).

Although there was no statistically significant difference between the EP and BFD polishing systems

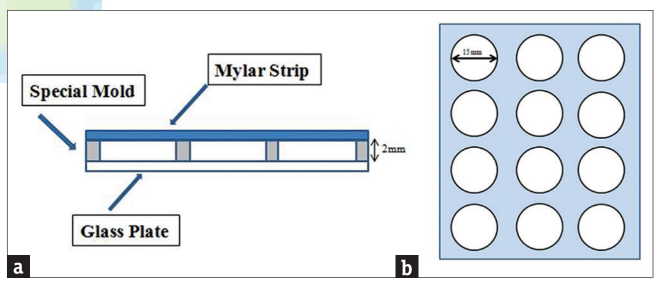

Figure 1: Schematic illustration of the composite producing apparatus: (a) Frontal view of the assembly, (b) Top view of the special mold

Table 1: Composite resin materials and their properties

Materials	Organic matrix	Filler size	Filler	Product	Manufacturer
Nanohybrid composite resin (inorganic filler ratio 89% of weight, 73% of the volume)	BIS-GMA, BIS-EMA, TEGDMA	0.5-3 µm, 20-40 nm	Glass ceramic and silicone dioxide - nanoparticles	GS	Voco, Cuxhaven, Germany
Nanohybrid composite resin (inorganic filler ratio 78% of weight, 66% of volume)	BIS-GMA	0.37-1.5 µm	Silanated barium glass and prepolymerized organic fillers	CME	Kuraray, Osaka, Japan
Hybrid composite resin (inorganic filler ratio 66% of weight, 85% of volume)	BIS-GMA, TEGDMA	0.6-3.5 µm	Zirconia, silica	VP	3M ESPE, St. Paul, USA
Micro-hybrid composite resin (inorganic filler ratio 81% of weight, 63% of volume)	BIS-GMA	0.05-0.9 µm	Silica, zirconia, barium glass particles	RC	Rubydent, Istanbul, Turkey

Bis-GMA=Bisphenol-A diglycidylether methacrylate; TEGDMA=Triethyelene glycol dimethacrylate; Bis-EMA=Ethoxylated bisphenol-A dimethacrylate; GS=GrandioSo, CME=Clearfil Majesty™ Esthetics; VP=Valux™ Plus; RC=Ruby Comp

Table 2: Polishing systems and their properties

Materials	Product	Manufacturer
Aluminum oxide coated cups and diamond micropolisher discs	EP	Dentsply, Konstanz, Germany
Aluminum oxide coated discs	BFD	Bisco Inc., Schaumburg IL, USA

BFD=Bisco finishing discs; EP=Enhance® and Pogo®

Table 3: The values of total color change of the composite resins

Composites	ΔE	
	Median	SEM
CME	5.00[a]	0.53
VP	10.95[b]	0.62
GS	7.04[c]	0.94
RC	7.16[c]	0.95

Same superscripts are not significantly different (P>0.05). SEM=Standard error of mean; GS=GrandioSo; CME=Clearfil Majesty™ Esthetics; VP=Valux™ Plus; RC=Ruby Comp

Table 4: The values of the total color change of the polishing systems

Polishing systems	ΔE	
	Median	SEM
C	12.95[a]	0.62
BFD	6.63[b]	0.48
EP	5.66[b]	0.45

Same superscripts are not significantly different (P>0.05). SEM=Standard error of mean; C=Control; BFD=Bisco finishing discs; EP=Enhance® and Pogo®

in the CME and VP groups (P > 0.05), a statistically significant difference was found in the GS and RC groups (P < 0.05). Among all of the composite resin groups, the C group showed the lowest surface roughness values.

Both the BFD and EP groups showed statistically significant differences among the composite

Table 5: The values of the surface roughness of the composite resins

Composites	Surface roughness (R_a)	
	Median	SEM
CME	0.31[a]	0.03
VP	0.27[a]	0.02
GS	0.32[a]	0.03
RC	0.27[a]	0.03

Same superscripts are not significantly different (P>0.05). SEM=Standard error of mean; SEM=Standard error of mean, GS=GrandioSo; CME=Clearfil Majesty™ Esthetics; VP=Valux™ Plus; RC=Ruby Comp

Table 6: The values of the surface roughness of the polishing systems

Polishing kits	Surface roughness (Ra)	
	Median	SEM
C	0.18[a]	0.01
BFD	0.28[b]	0.01
EP	0.49[c]	0.02

Different superscripts are significantly different (P>0.05). SEM=Standard error of mean, C=Control; BFD=Bisco finishing discs; EP=Enhance® and Pogo®

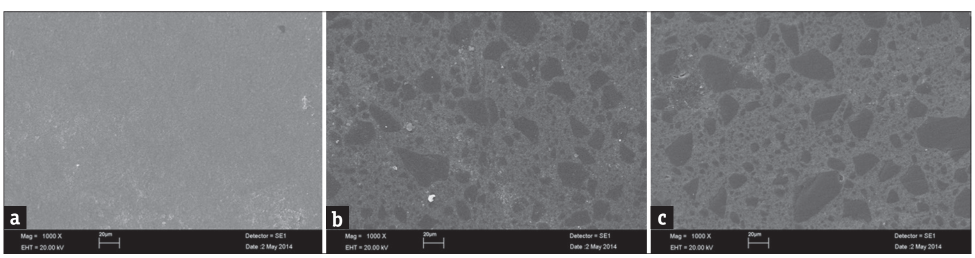

Figure 2: Scanning electron microscope images of Valux Plus™ (a) Control, (b) Enhance® and PoGo®, and (c) Bisco finishing discs groups

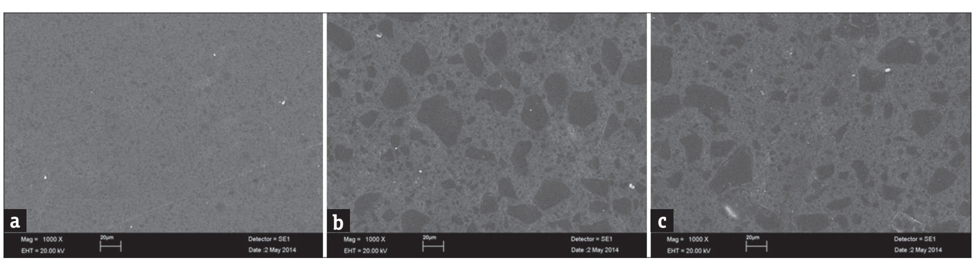

Figure 3: Scanning electron microscope images of Clearfil Majesty™ Esthetic (a) Control, (b) Enhance® and PoGo®, and (c) Bisco finishing discs groups

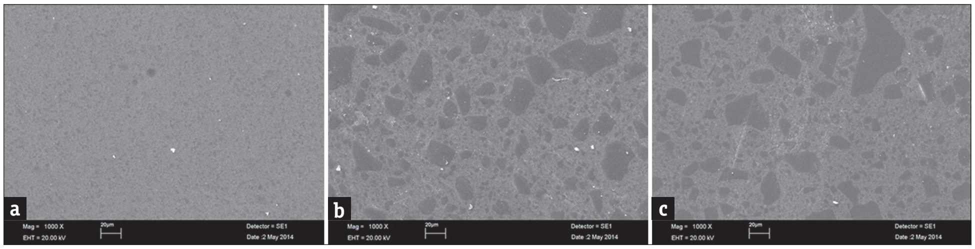

Figure 4: Scanning electron microscope images of GrandioSo (a) Control, (b) Enhance® and PoGo®, and (c) Bisco finishing discs groups

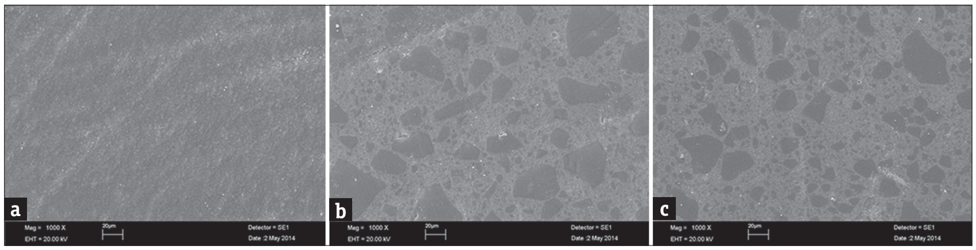

Figure 5: Scanning electron microscope images of Ruby Comp (a) Control, (b) Enhance® and PoGo®, and (c) Bisco finishing discs groups

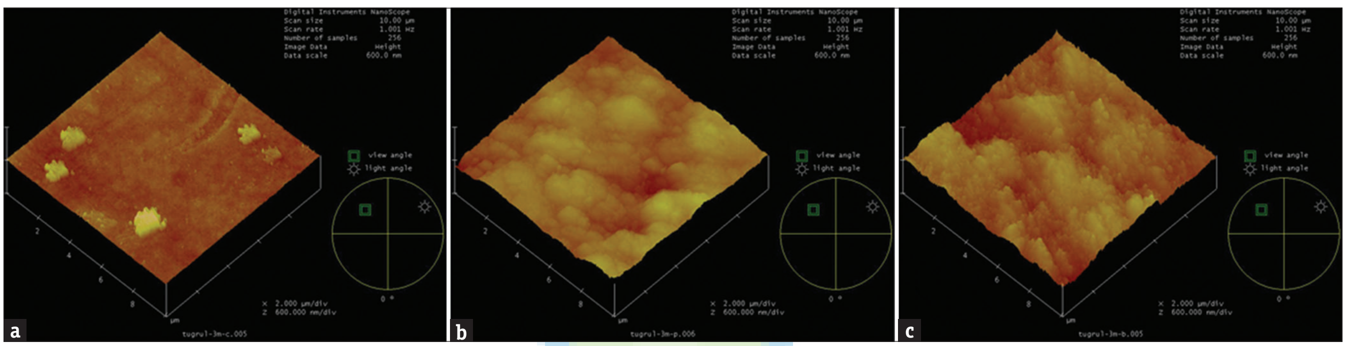

Figure 6: Atomic force microscope images of Valux™ Plus (a) Control, (b) Enhance® and PoGo®, and (c) Bisco finishing discs groups

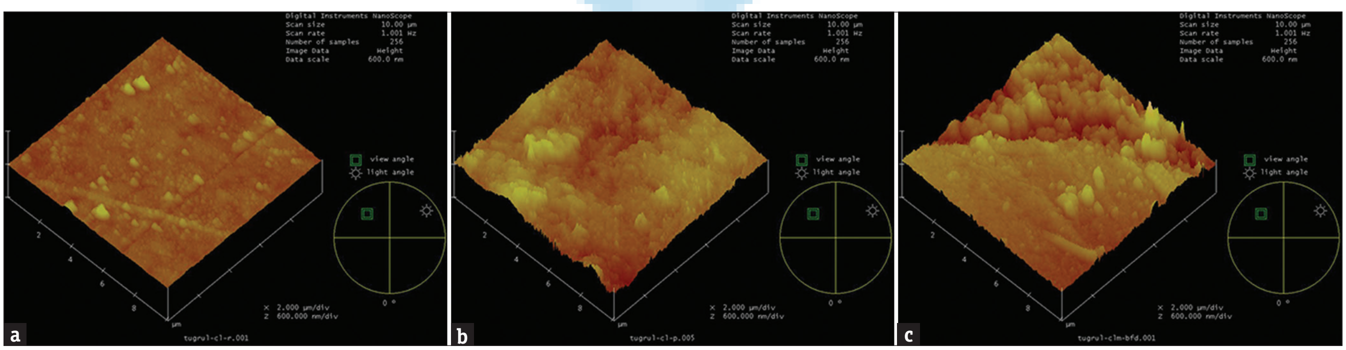

Figure 7: Atomic force microscope images of Clearfil Majesty™ Esthetic (a) Control, (b) Enhance® and PoGo®, and (c) Bisco finishing discs groups

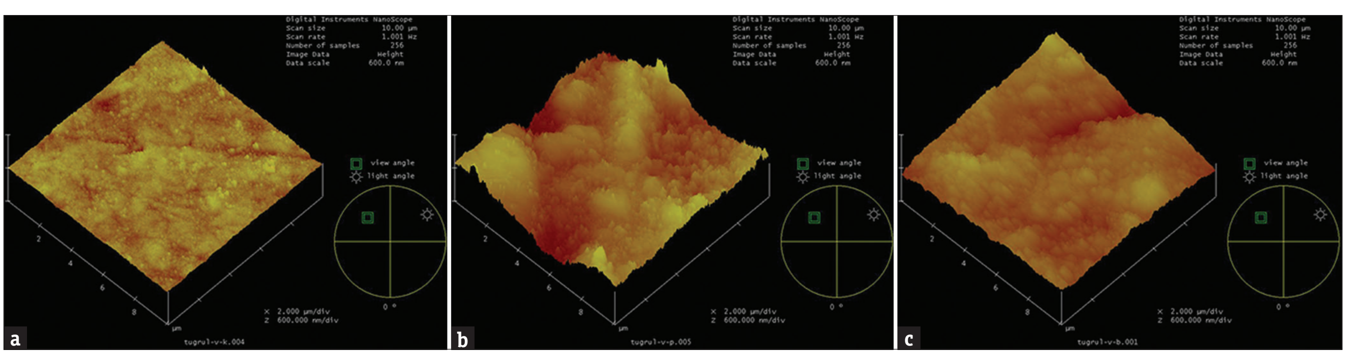

Figure 8: Atomic force microscope images of GrandioSo (a) Control, (b) Enhance® and PoGo®, and (c) Bisco finishing discs groups

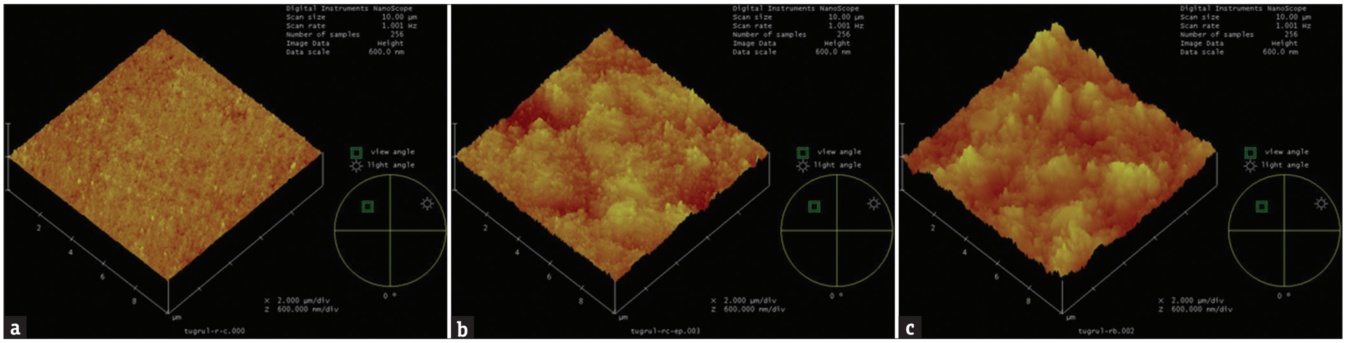

Figure 9: Atomic force microscope images of Ruby Comp (a) Control, (b) Enhance® and PoGo®, and (c) Bisco finishing discs groups

resins ($P < 0.05$), while in the general evaluation, the EP polishing system showed rougher surfaces.

Relation between color difference and surface roughness values

The results of the regression analysis indicated that a statistically significant correlation was found between the Ra and ΔE values ($P < 0.05$, $r^2 = 0.74$), indicating that these two variables were correlated at 74% with each other.

Scanning electron microscope and atomic force microscope images of surface topography

Scanning electron microscope observations

The SEM analysis showed good agreement with the data. The C groups showed homogenous surface textures [Figures 2a, 3a, 4a, and 5a], and both polishing systems exhibited similar morphologies in the composite resins. A high density of inorganic fillers of the composite resin is shown the micrographs [Figures 2b and c, 3b and c, 4b and c, and 5b and c].

Atomic force microscope observations

The C groups showed homogenous surface textures [Figures 6a, 7a, 8a, and 9a], whereas the EP polishing systems showed uniform irregularities in the CME and RC [Figures 7b and 9b, respectively]. The EP and BFD polishing systems showed uniform irregularities in the VP [Figures 6b and c, respectively], and the BFD polishing system showed uniform irregularities in the GS [Figure 8c]. The EP polishing system showed deep scratch lines in the GS [Figure 8b], and the BFD polishing system showed deep scratch lines in the CME [Figure 7c] , and in the RC [Figure 9c].

Discussion

In this study, based on the data obtained, the first hypothesis was rejected since there was a significant difference between polishing systems; the second hypothesis was rejected since there was a significant difference in terms of color stability, but there was no difference in terms of surface roughness among the composite resins.

In order to understand the surface texture of dental materials, specific devices called profilometers have been used to measure surface roughness.[6,17-19] However, this measurement method is limited because only numerical or quantitative values can be obtained.[20] SEM can be used to show contour changes that may not be evaluated by the profilometer, but SEM has limitations because it cannot define three-dimensional surface topography. AFM has recently been used in dentistry to obtain three-dimensional detailed topographical images of surface roughness.[21] For the present study, the surface roughness values of each specimen were measured by means of a profilometer because of practical usage, cheap cost, and obtaining numerical values. In addition, SEM and AFM observations were made to evaluate contour changes and three-dimensional surface topography.

Generally, it is believed that surface roughness is associated with the filler size of the composite resins.[6,22] Previous studies have mentioned that resin composite resins with smaller filler sizes promote smoother surfaces.[6,23,24] In the present study, there was no significant difference among the composite resins, whereas the nanohybrid composite resins GS and CME exhibited similar surface roughness with the micro-hybrid composite resin RC. This finding was unexpected, but the RC's filler contents were similar to the others [Table 1]. In literature, it is possible to find similar results. Gönülol and Yılmaz[17] tested the surface roughness of composite resins and reported that no significant difference was found between micro-hybrid and nanohybrid composite resins. These results are also similar to those of the study by de Costa *et al*.[23]

In this study, the rough surfaces were obtained in the CME group in both polishing groups. According to Iazzetti *et al*.,[5] glass particles in composite resins cause high porosity, and CME includes silica and barium glass fillers for the inorganic content. Therefore, because of the inclusion of the glass particles, the CME could show higher R_a values.

The finishing and polishing of composite resin restoration are necessary stages[9] and provide better clinical outcomes.[25] A high degree surface roughness can cause plaque accumulation, gingival irritation, and caries.[26] In this study, all of the surface roughness values that contained two finishing or polishing systems were >0.2 µm, which is the critical size for bacterial adhesion.[6] Unlike ceramic materials, composite resins are subject to wear over time because of chewing forces; therefore, as long as the composite resin material is in the mouth, its surface may become smoother over time.[6] In the C groups, for all composite resins, the smoothest surfaces were obtained, which was in accordance with literature.[6,27,28] In this study, both of the polishing systems showed higher R_a values than the C group, and the surface roughness of all the composite resin materials cured against the Mylar strip were similar. However, because this polymerized surface is rich in organic matrix and less resistant to abrasion, it is not preferred.[29]

The BFD group generally showed lower surface roughness values than the EP group. In many studies, the lower surface roughness values were achieved using aluminum oxide discs.[20,30,31]

Although there are several studies[6,7,17,20,32] including the polishing systems, a study could not be found which evaluated the BFD polishing system and RC composite resins. As a working principle, the BFD is similar to the Sof-Lex finishing discs (3M, USA). In addition, the current study data obtained from the BFD was similar with Gönülol and Yılmaz,[17] and higher than Berger *et al*.[33] which evaluated Sof-Lex finishing discs.

One reason for obtaining a smoother surface with the BFD was that when polishing times were evaluated, the use of four BFD had a longer polishing period than the EP. In literature, it has been noted that the time used for the polishing procedures might have influenced the surface roughness.[34] Moreover, van Dijken *et al*.[35] reported that the aluminum oxide discs abrade resin matrices and filler particles equally, and they achieve smoother surfaces.

Regarding the color differences after the finishing and polishing procedures, the C groups in all composite resins were similar and had significant discoloration. This finding is in accordance with Gönülol and Yılmaz.[17]

The intrinsic factors include the discoloration of the resin material itself, whereas the extrinsic factors include staining by the absorption of coloring agents.[1]

The literature has reported the discoloration of composite resins occurring when they were exposed to different staining media, such as coffee, cola, tea, and fruit juice.[36,37] In the current study, coffee was used as a coloring agent because of its frequent consumption in daily life.

Because the maximum water sorption of composite resins occurs during the first 24 h,[38] the specimens were stored in distilled water at 37°C for 24 h, before the experimental study. In addition, this situation simulated the 1st day of service for the intraoral restorations.

For measuring the discoloration, spectrophotometers and colorimeters may be used, and there are several studies that evaluate the color differences of dental materials using colorimeters[39,40] and spectrophotometers.[1,17] In the present study, a colorimeter was used, and according to the working principle of the colorimeter, the specimens had to be at least 15 mm in diameter; therefore, the specimens were 15 mm in diameter.

The CIE L*a*b* color measuring system is recommended for dental purposes. In the literature, $\Delta E > 1$ was generally found to be visually perceptible, and $\Delta E \geq 3.7$ was found to be a poor color match value.[39] In the present study, all of the composite resin groups revealed values that were >3.7 after the 48 h coffee storage. One reason for obtaining high ΔE values in the composite resins is that one side of the specimens was polished, and color reflection in the unpolished surface might have occurred.

Pires-de-Souza Fde *et al*.[41] reported that resin plays a major role in the discoloration of composite resins, and composite resins that have trimethylene glycol dimethacrylate (TEGDMA) in their compositions release large amounts of monomers in aqueous media when compared with Bisphenol-A diglycidylether methacrylate and UDMA.[36,42] The highest ΔE value was in the VP group, and the Valux™ Plus had TEGDMA in their organic chemical composition.

In the present study, there was a statistically significant correlation between surface roughness and color change. Previous studies have reported that, besides material composition, the finishing and polishing procedures might also influence composite resin surface quality, and that rough surfaces exhibit high staining.[43,44] The structure of a resin composite resin and the characteristics of particles have a direct impact on surface smoothness and susceptibility to extrinsic staining.[45]

Conclusion

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

- Among the resin composite resins tested, the VP group showed the highest color change, whereas the lowest color change was seen in the CME group
- There was no significant difference among the

composite resins in terms of surface roughness; in addition, the BFD presented smoother surfaces than the EP
- There was a statistically significant correlation between the surface roughness and the color differences values.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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