Original Article

Assessment of the Effect of Finishing and Polishing and In-Office Bleaching on Surface Roughness of Commercially Available Resin Composites: An In-Vitro Study

Aiah A. El-Rashidy [1*], Omar Shaalan [2,3]

[1] Biomaterials Department, Faculty of Dentistry, Cairo University, Egypt
[2] Conservative Dentistry Department, Faculty of Dentistry, Cairo University, Egypt
[3] Conservative Dentistry Department, School of Dentistry, Newgiza University, Egypt

Email: aiah.abdelwahab@dentistry.cu.edu.eg

Abstract

Aim: The aim of the current study was to evaluate the effect of finishing and polishing and an in-office bleaching gel on the surface roughness of single-shade (Omnichroma) and group-shade (Estelite Alpha) resin composites. **Methodology:** A total of ten composite disc-shaped specimens; five specimens for each material were prepared using Teflon mold (1-mm thick and 8-mm diameter). The resin composites were cured against mylar strips to produce flat smooth surface of the tested specimens. Then each disk was finished and polished using multi-step finishing and polishing system (Astropol, Ivoclar Vivadent). Each specimen was bleached using an in-office bleaching system two times in a row using 38% hydrogen peroxide (H_2O_2). The average surface roughness (R_a, in μm) of the specimens was measured using non-contact optical profilometry at baseline, after finishing and polishing, and after bleaching procedure. Intergroup comparison was performed using independent t-test, while intragroup comparison was performed using one-way ANOVA followed by Tukey post-hoc. **Results:** Comparison between both materials has revealed statistically significant difference at baseline (P = 0.0086), with Estelite Alpha showing higher surface roughness. However, after polishing and bleaching there was no statistically significant difference between both materials (P = 0.5796 and P = 0.3010) respectively. **Conclusion:** The surface roughness of resin composites is material dependent. Omnichroma demonstrated lower initial R_a value than Estelite Alpha. However, Omnichroma showed significant increase in surface roughness following finishing and polishing, unlike Estelite Alpha. Bleaching with 38% H_2O_2 showed no effect on the surface roughness of both materials.

Keywords: Resin composite; Surface roughness; Single-shade; Finishing and polishing; Bleaching.

I. INTRODUCTION

Increased esthetic demands is common nowadays, especially in dentistry, as currently one of the prime requirements of dental patients is to have highly esthetic dental restorations mimicking natural teeth in appearance and esthetics [1,2]. Resin composites are considered the most commonly used direct esthetic restorative materials owing to their ability to conservatively restore lost tooth structure and modifying tooth shape and color, simulating the natural tooth [3,4]. The esthetic concerns relates mostly to shade matching and optimal adaptation to adjacent natural tooth structure [4]. Natural teeth have a polychromatic nature which makes shade matching with synthetic restorative materials more challenging [5].

Clinicians nowadays are challenged to mimic the natural teeth color and appearance through selecting the optimal restorative material and placement technique.

However, the clinical longevity of resin composites are commonly compromised by their susceptibility to staining in the oral environment [6] due to several extrinsic and/ or intrinsic factors [7,8]. In addition, one of the main factors that contributes to clinical success of esthetic resin composite restorations is their surface quality, which depends on the preservation of the surface smoothness of the restoration [9,10]. Increased surface roughness of dental restorations is reported to increase staining susceptibility of the restoration, which will affect the esthetic qualities of such restorations [11,12], a linear relation was found between increased surface roughness and increased discoloration tendency [12]. In addition, increased surface roughness was reported to promote plaque accumulation, with subsequent increased susceptibility to recurrent caries, gingival irritation, and periodontal disease [13,14]. It is suggested that an average roughness value (R_a) of 0.2 µm is considered the threshold value for bacterial plaque retention [15,16]. Thus, preservation of surface smoothness of esthetic resin composite restorations is an important requisite.

Finishing and polishing of resin composite restorations is a routine clinical procedure, where finishing aims to remove surface defects and excess material and to adjust the restoration anatomy, while polishing eliminate surface roughness resulting from the finishing step to obtain glossy and smooth surface, mimicking the adjacent natural enamel [17]. In addition, bleaching is one of the most commonly employed esthetic dental treatment for stained natural teeth, being a minimally invasive, safe, economical, and effective option [18]. Unfortunately, bleaching agents may adversely affect the physical properties and surface characteristics of composite restorations, altering their surface roughness due to their peroxide content [15].

Thus, the aim of the current study is to evaluate the effect of finishing and polishing and an in-office bleaching gel, containing 38% hydrogen peroxide, on the surface roughness of two commercially available resin composites, single-shade (Omnichroma) and group-shade (Estelite Alpha) resin composites. The two null hypotheses tested were that there is no difference in the surface roughness of both composites after finishing and polishing and after bleaching.

II.   MATERIALS AND METHODS

The materials used in the current study are described in table 1.

A. Sample Size Calculation

In a previous study by Markovic et al in 2014 [19], the surface roughness within resin composite subjected to bleaching agent (38% hydrogen peroxide) was not normally distributed with median of 77.09 and range of (69.39-90.88). Median and range were converted to mean and standard deviation of 78.6±6.2 [20]. If the true difference in the experimental and control means is 12, we will need to study 5 experimental subjects per group to be able to reject the null hypothesis that the population means of the experimental and control groups are equal with probability (power) 0.8. The type I error probability associated with this test of this null hypothesis is 0.05. Sample size was calculated using PS Power and Sample version 3.1.6 for windows using independent t test.

B. Specimens' Preparation

A total of ten composite disc-shaped specimens were used in the current study, five specimens for each material, using a 1-mm thick and 8-mm diameter teflon mold. After the resin composites were placed in the molds, mylar strips and microscope glass slides were applied over the top surface of the resin composites using finger pressure to produce flat smooth surface of the tested specimens. Each sample was light-cured through the mylar strip and the glass slide using a light-emitting diode (LED) curing unit (Mini LED, Satelec, Acteon, France), at a light intensity of 1,000 mW/cm^2, for 20 s (Omnichroma) and for 30 s (Estelite Alpha) according to the manufacturer's recommendations. The light intensity of the LED curing unit was checked with a spectroradiometer (Demetron Research

Corp. USA). Then each disc was finished and polished using multi-step finishing and polishing system (Astropol, Assortment, Ivoclar Vivadent, Buffalo, NY, USA), according to the manufacturer's instructions. First, the surface was finished using grey cup shaped finishing tool (Astropol F), then Astropol P (green) was used for polishing and finally for high gloss polish Astropol HP (pink) was used.

C. Bleaching

Each specimen was bleached using an in-office bleaching system two times in a row using 38% H_2O_2 (The Smile® Strong Complete, Unica Group, Italy) according to the manufacturer's instructions for 15 minutes each time. After each bleaching cycle the surface of specimens was thoroughly rinsed with water and air dried.

D. Surface Roughness Evaluation

The average surface roughness (R_a, in μm), of the specimens was measured using non-contact optical profilometry. The surface roughness for each disc was assessed at baseline (as-prepared discs), after finishing and polishing, and after bleaching procedure. Each specimen was imaged using USB Digital microscope at a fixed magnification of 120X using built-in 8 LED camera (U500X Capture Digital Microscope, Guangdong, China), and images were analyzed using WSxM software (Ver 5 develop 4.1, Nanotec, Electronica, SL) to determine the average height of peaks on the surface, which is commonly utilized as a reliable indicator of surface roughness [21]. For each specimen, three-dimensional (3D) images of the surface profile were created for three areas, at the center and at the sides, and an average value was reported for each specimen.

E. Statistical Analysis

Data were analyzed using Medcalc software, version 19 for windows (MedCalc Software Ltd, Ostend, Belgium). Data were explored for normality using Kolmogrov Smirnov test and Shapiro Wilk test. Continuous data showed normal distribution and were described using mean and standard deviation. Intergroup comparison was performed using independent t-test ($P \leq 0.05$), while intragroup comparison was performed using one-way ANOVA followed by tukey post-hoc test (Bonferroni corrected $P \leq 0.0166$).

III. RESULTS

The surface roughness measurements obtained at different stages are shown in Table 2. Comparison between both materials has revealed statistically significant difference at baseline ($P = 0.0086$), where Omnichroma showed less R_a value than Estelite Alpha. However, after polishing and bleaching there was no statistically significant difference between both materials ($P = 0.5796$ and $P = 0.3010$) respectively. Intragroup comparison within Omnichroma have shown statistically significant difference between baseline and after polishing and bleaching ($P = 0.002$), the least R_a value was shown at the baseline. Intragroup comparison within Estelite Alpha has shown no statistically significant difference between baseline and after polishing and bleaching ($P = 0.265$). Figure 1 shows the 3D image of the surface profile of a representative specimen from each group. The same specimen was imaged at baseline, following finishing and polishing, and after bleaching.

IV. DISCUSSION

The optimal shade matching of esthetic restorative materials to the surrounding natural tooth structure is one of the prime requirements of esthetic dentistry. To simplify the shade matching procedures, manufacturers have developed group-shade and most recently single-shade composites [22]. The investigated materials in the current study rely on the chameleon or blending effect to recreate the color and blend in with the surrounding tooth structure, utilizing spherical submicron-sized fillers, 260 nm in Omnichroma and 200 nm in Estelite Alpha. Surface irregularities on rough surfaces could aid in the bacterial attachment, as they protect the bacteria from salivary flow [13]. It was reported that the adhesion of streptococcus mutans was enhanced on rough surfaces of different filling materials [23,24]. In addition to affecting the esthetics, through increasing the susceptibility to extrinsic discoloration [11,12]. Therefore, restorative materials should have and maintain a smooth surface finish. Regarding the surface qualities of esthetic resin composite restorations, several factors may influence the roughness of the restorations, including the organic matrix composition, size, shape, distribution, loading, and composition of the fillers [17,25,26].

Table 1: Materials' manufacturer, filler type, filler content, matrix composition and shade:

Product	Manufacturer	Filler type	Filler content (weight)	Matrix composition	Shade	Lot number
Omnichroma (single-shade composite)	Tokuyama Dental, Tokyo, Japan	Uniform sized supra-nano spherical filler (260 nm spherical silica-zirconia) and composite filler.	79%	UDMA[1] and TEGDMA[2]	Universal	1615
Estelite Alpha (group-shade composite)	Tokuyama Dental, Tokyo, Japan	Submicron (200 nm) silica-zirconia spherical filler and composite filler	82%	Bis-GMA[3] and TEGDMA	A2	E6921

[1] UDMA = urethane dimethacrylate, [2] TEGDMA = triethylene glycol dimethacrylate, [3] BisGMA = bisphenol A diglycidildimethacrylate.

Table 2. Mean and standard deviation of surface roughness (R_a) of both materials.

	Omnichroma		Estelite Alpha		Mean difference		
	Mean (µm)	SD	Mean (µm)	SD	Mean	SD	P value
Baseline	0.20[a]	0.06	0.25	0.02	0.05	0.05	P = 0.0086*
Polished	0.26[b]	0.03	0.25	0.03	0.006	0.03	P = 0.5796
Bleached	0.25[b]	0.04	0.23	0.06	0.021	0.05	P = 0.3010
P value	P = 0.002*		P = 0.265				

*Means with different letters are statistically significant, * corresponds to statistically significant.*
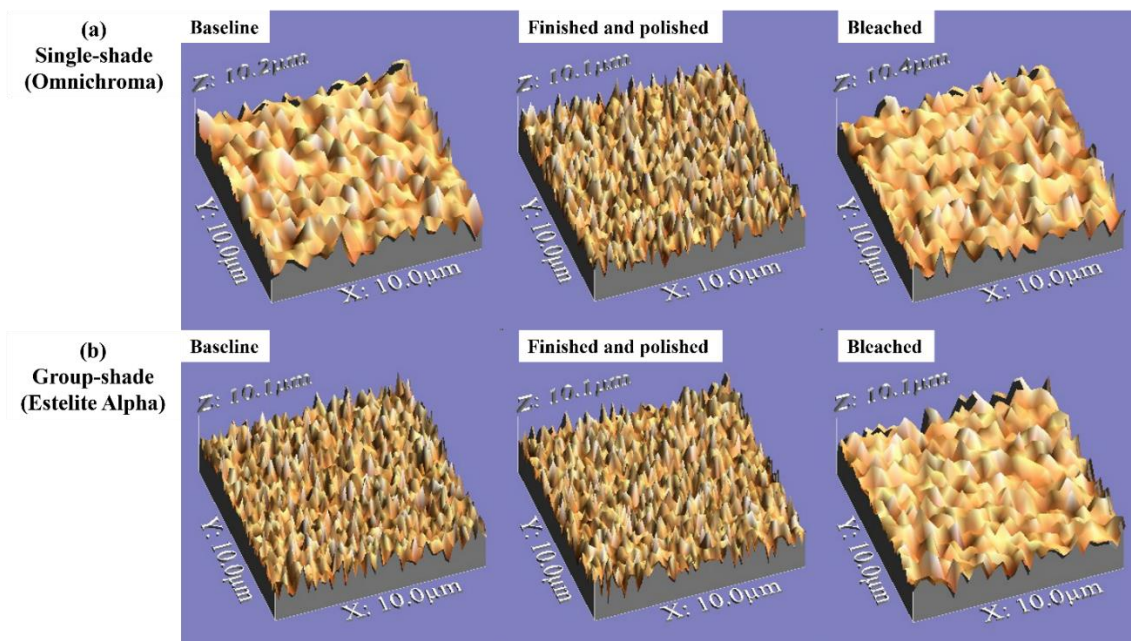

Figure 1. 3D image of the surface profile of Omnichroma (a) and Estelite Alpha (b), at baseline, following finishing and polishing, and after bleaching.

Several techniques are available for surface roughness characterization, including contact and non-contact methods, which could be either qualitative or quantitative. Among the quantitative methods, mechanical stylus, optical and scanning probe microscopy (including atomic force microscopy (AFM)) are the most common measuring methods [27]. The stylus profilometry technique cannot detect roughness smaller than the stylus tip radius [28], and the stylus tip can scratch the surface during measurements [27], which would interfere with evaluating the same specimen after different treatments. On the other hand, AFM scan small areas with high resolution, providing data at the nano-scale level, however the relatively small scanned areas represent a limitation of AFM, in addition to being complex to use [27]. In the current study, the surface roughness of the investigated materials was examined using non-contact, optically based method to avoid any surface damage to the specimens during measurement.

Smooth and polished surfaces of the specimens were obtained through curing the material against mylar strip and glass slide, which were used as control (baseline), as it is reported to produce an optimally smooth surfaces when compared to the available different finishing and polishing systems [29–31]. However, curing against mylar strip produces a resin matrix-rich surface layer, resulting in lower resistance of resin composites to surface discoloration and degradation, and lower surface hardness, thus it is clinically unacceptable and it is strongly advised to remove this resin-rich layer by finishing and polishing [32–34].

Figure (1) shows Omnichroma surface to exhibit lower surface roughness when compared to Estelite Alpha. This was also evident by R_a values recorded at baseline (Table 1), where the surface roughness of Omnichroma at baseline did not exceed the threshold value of 0.2 μm R_a, while Estelite Alpha showed higher roughness value. The predominant factor affecting the surface qualities of the as-prepared specimens, being cured against the mylar matrix and having a matrix-rich surface layer, may be attributed to the nature of the organic matrix [35], not due to the effect of the filler particles. Thus, the difference in the surface roughness of the investigated groups could be attributed to the difference in their matrix composition. The matrix of Omnichroma is based on UDMA and

TEGDMA, while that of Estelite Alpha is based on Bis-GMA and TEGDMA.

The surface roughness of Omnichroma was significantly increased following finishing and polishing, while no significant difference was observed in the Estelite Alpha group. The finishing and polishing procedures could contribute to increased surface roughness due to the removal of the soft resinous matrix, leaving the harder filler particles protruding from the surface [30]. Thus, it was widely accepted that the size, shape, quantity, and hardness of filler particles greatly impact the polishability of resin composites [30]. This could be explained based on the smaller the filler particles, and the higher filler loading, the smaller the inter-particle spacing, thus protecting the softer organic matrix against wear during the polishing procedure resulting in increased smoothness [33,35,36]. However, there is conflicting data in the literature about the effect of average filler size and surface roughness, and several studies have concluded that smaller filler size don't essentially result in lower surface roughness following the polishing procedure [37,38]. Both materials used have spherical submicron-sized particles with small size differences, where the particle size of Estelite Alpha is 200 nm while that of Omnichroma is 260 nm. Thus, the nature of the organic matrix and its wear resistance may contribute to such differences following finishing and polishing [39]. Söderholm et al. [39] stated that the resin matrix composition is the main factor affecting the wear resistance.

In the current study, Estelite Alpha specimens showed higher resistance to changes in their surface roughness following finishing and polishing. This was unexpected, as UDMA-based composites were reported to exhibit higher wear resistance than Bis-GMA-based composites [39,40], thus it was expected that Omnichroma would show higher resistance to abrasion during finishing and polishing, but this was not the case. However it should be noted that it was previously reported that the microhardness of unfilled Bis-GMA-based resin was higher than UDMA-based resin [40]. It also should be noted that the wear resistance of the matrix is not only affected by the main oligomer but may also be affected by the amount of diluent (TEGDMA) added. Which is a detail that was not highlighted by the manufacturer of both products, as it was reported that UDMA- and Bis-GMA-based resins demonstrated increased

wear resistance with increasing the content of TEGDMA [41,42]. Thus, the ratio of the different components in the matrix of both materials needs further investigations to clearly understand its effect on the surface roughness.

To evaluate the effect of bleaching on the surface roughness of the two investigated materials, both materials were bleached using an in-office bleaching system containing 38% H_2O_2. Bleaching may lead to the chemical degradation of the organic matrix and/or the coupling agent by the action of the employed peroxide. There is contradictory data on the effect of bleaching on the surface roughness of resin composites. Increased surface roughness was reported following bleaching, which was attributed to the release of free radicals from peroxides, disrupting the filler-resin bond interface [43,44] and causing hydrolytic degradation of the matrix phase [45]. Others reported decreased surface roughness following bleaching [46], due to the effect of peroxides and the released free radicals on eroding the surface through removing the minerals from fillers protruding on the surface following finishing and polishing, thus resulting in smoother surfaces [46]. Some others reported no change in surface roughness following bleaching [45,47,48]. This could be attributed to the fact that the effect of bleaching on the surface qualities of different resin composite materials is dependent on both the resin composite material and the bleaching agent used and the recommended time of bleaching [45]. Langsten et al. [49] stated that using higher-concentration bleaching agent as recommended by the manufacturer presents no significant risk to the surface of resin composite restorations. Polished samples are reported to exhibit higher stability against the effect of bleaching, as compared to unpolished ones. This may be attributed to the presence of the resin-rich surface layer in unpolished samples which is more susceptible to the detrimental effects of the bleaching agents, as compared to the finished/polished surfaces which are rich in fillers and are more representing to the bulk properties of the material [45].

In the current study, there was no statistically significant difference in the roughness between both groups after bleaching of the finished/polished specimens (table 1), which is in accordance with the results of Telang et al. [50], who reported that resin composite containing supra-nano sized fillers exhibited minimal change in surface roughness following bleaching.

According to the findings of the current study, the first null hypothesis can be partially rejected, as the surface roughness of Omnichroma increased after finishing and polishing. While the second null hypothesis could not be rejected as there was no difference in the surface roughness after bleaching.

Limitations of the current study include the accuracy of the surface roughness detection in relation to the particle size, it was reported that surface roughness changes may be not be clearly if fillers size are much smaller than 1 μm [51]. Thus, the detection limit of instruments/ methods used for roughness evaluation should be carefully considered. In addition, the effect of resin matrix composition on the surface roughness of resin composites needs further investigations.

V.   CONCLUSION

Within the limitations of the current study, it could be concluded that the surface roughness of resin composites is material dependent. Omnichroma demonstrated lower initial R_a value than Estelite Alpha. The effect of finishing and polishing procedure varies according to the material, where Omnichroma showed significant increase in surface roughness following finishing and polishing, unlike Estelite Alpha. Bleaching with 38% H_2O_2 showed no effect on the surface roughness of both materials. Matrix composition affected the surface roughness of both materials at baseline and after finishing and polishing.

Conflict of Interest

Funding

Ethics
This study protocol was approved by the ethical committee of the faculty of dentistry-Cairo university on: 31/10/2023, approval number: 30-10-23.

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