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Effects of Bleaching on Surface Roughness and Color of Two Types of Composite Resins Subjected to Two Surface Polishing Methods

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Abstract

Background and Aim: This study aimed to evaluate the effects of bleaching on surface roughness and color of two types of composite resins namely Gradia (hybrid microfilled) and Omnichroma (super-nano filled), subjected to two polishing methods.

Materials and Methods: In this in vitro study, 100 composite specimens (50 Gradia and 50 Omnichroma) were fabricated and divided into two groups for polishing with disc and bur systems. The baseline surface roughness and color parameters (L*, a*, b*) were recorded. The specimens were immersed in a tea solution for 24 days to simulate staining, followed by in-office bleaching with 38% hydrogen peroxide. Surface roughness and color parameters were re-measured post-bleaching. Statistical analysis was performed using repeated-measures ANOVA to assess the effects of bleaching, polishing method, and composite type (alpha=0.05).

Results: The interaction effect of polishing method and composite type on surface roughness was not statistically significant ($P>0.05$). A significant change was observed in ΔL after polishing compared with the baseline ($P = 0.018$), indicating an increase in lightness for Omnichroma. For Δa, Gradia composite polished with disc exhibited significant redness after immersion in tea ($P=0.022$), while Δb results showed that Gradia had a significant shift to yellowness across all stages ($P<0.05$).

Conclusion: The results showed that the surface roughness of both Gradia and Omnichroma composite resins increased after bleaching. Gradia exhibited more pronounced ΔE, particularly turning redder after immersion in tea, whereas Omnichroma displayed better color stability. These findings suggest that material selection and polishing methods are critical in maintaining esthetic outcomes in bleached composite restorations.

Keywords: Color; Composite Resins; Tooth Bleaching; Dental Polishing; Surface Properties

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Introduction

Patients always seek an attractive smile because it is synonymous with health, proper appearance, and professional and social benefits. Tooth color is just one facet of facial beauty; however, being immediately noticeable, it is deemed the most significant factor [1]. Today, with the increasing demand for beauty, various esthetic methods have become popular. Bleaching is the most conservative and one of the most requested treatments by patients. Tooth bleaching is performed through at-home or in-office bleaching methods, using 15% carbamide peroxide and 35%–38% hydrogen peroxide, respectively. Carbamide peroxide is the most common bleaching agent for home bleaching; while hydrogen peroxide is the most effective agent for removing intrinsic discolorations in the office. Bleaching treatment may have various adverse effects due to oxidative reactions on the tooth structure and restorative materials [2-5]. During in-office bleaching, hydrogen peroxide directly reacts with water and oxygen in macromolecules of pigments. During at-home bleaching, carbamide peroxide is converted to hydrogen peroxide and urea. Urea is then decomposed into ammonium and carbon dioxide. The longer the exposure time and the higher the concentration of the bleaching agent, the more satisfactory the oxidation will be [2-4]. During bleaching, not only the surface of teeth but also the surface of existing restorative materials comes into contact with the bleaching agent, which can compromise the physical properties, and mainly the surface roughness of composite resins in high concentrations. The surface roughness of composite resins affects their optical properties and bacterial adhesion. These changes are influenced by the composition and percentage of inorganic and organic phases in the composite resin, type and concentration of the bleaching agent, bleaching time and technique, and quality of finishing and polishing steps [4,6,7]. Due to the desire of most patients, who nowadays opt for cosmetic restorations, veneers, and extensive in-office bleaching treatments, various studies have evaluated the effects of bleaching agents on properties such as tensile and shear strength of composite resins [8-10]. On the other hand, due to advances in science and technology, new dental materials and composite resins are introduced every day. The clinical success of composite resin restorative materials largely depends on their color stability over time.

Omnichroma (Tokuyama) is a new composite resin that, according to the manufacturer, has used structural color technology as the primary color mechanism for the first time in the world. No dyes or pigments have been added to it, and the filler creates a red-to-yellow color that matches the color of the surrounding teeth. This composite resin is made of 260-nm supra-nano filled spherical ZrO_2-SiO_2 particles, allowing it to match all 16 Vita shades. According to the manufacturer's claim, there will be color matching both before and after bleaching [11].

Color can be determined and evaluated visually or by using instrumental methods. Spectrophotometry and colorimetry are the most commonly used tools to determine the color change (ΔE) of restorative materials. Computational ΔE is represented in L*, a*, and b* parameters, which are the color coordinates of different samples or the same sample in different conditions [3]. It is crucial to be aware of the effect of bleaching procedures on the properties and behavior of composite resins to reduce the need for restoration replacement due to potential complications of bleaching procedures [12, 13]. The effect of bleaching agents on color stability of composite resins has been previously studied. However, some studies did not find a significant color difference after applying 10%–20% carbamide peroxide, reporting that changes in the color and whiteness of composite resins after tooth bleaching were not visually apparent [4, 14, 15]. Studies investigating the effects of bleaching agents on composite resins with synthetic pigments have demonstrated that exposure to bleaching agents leads to inherent destruction of composite resins and changes in their optical properties [16, 17].

Today, various finishing and polishing tools are utilized with different protocols, including diamond burs, carbide finishing burs, rotary diamond ceramic-coated instruments, rubber discs impregnated with aluminum oxide, silicon discs, and wheels [18]. The quality of finishing and polishing processes significantly influences the durability of restorations. Smooth surfaces reduce plaque retention, gingival irritation, the frequency of caries, and discoloration of restorations. Conversely, an increase in surface roughness enhances the accumulation of food debris and biofilm formation and raises the risk of periodontal disease [6]. It is also important to determine the best finishing and polishing technique for oral hygiene considerations. For these reasons, the finishing and polishing stages of composite resins are very important in dental treatments [7].

Therefore, considering the significance of finishing and polishing of composite resins, the widespread application of bleaching treatments, and the current deficiencies and research gaps, the present study was conducted to investigate the effect of bleaching on the surface roughness and color stability of Gradia (microfilled hybrid) and Omnichroma (super-nanofilled) composite resins.

Materials and Methods

The protocol of this in vitro study was approved by the Ethics committee of Tehran University of Medical Sciences, Faculty of Dentistry (Ethical code: IR.TUMS.DENTISTRY. REC.1400.047). In this in vitro study, 100 composite resin specimens were fabricated using two types of composite resins: Omnichroma (super-nanofilled; Tokuyama Dental, Japan) and Gradia (microfilled hybrid; GC Corporation, Tokyo, Japan) (Table 1). The specimens were fabricated using a Teflon mold measuring 5 mm in diameter and 2 mm in height. A smooth surface was achieved by placing a polyester tape on the composite resin, followed by the placement of a glass slab to ensure uniform thickness during curing. Each specimen was light-cured for 20 seconds per side (40 seconds total) using a LED curing unit (Demi; Kerr Corporation, USA). After curing, all specimens were immersed in distilled water at 37°C for 24 hours to complete polymerization. Their initial color (E0) was measured using an Easy Shade spectrophotometer (VITA Zahnfabrik, Germany) following the CIE L*a*b* color space. The initial surface roughness was measured using a profilometer (Time Group, China). Color measurements were made in triplicate for each disc, with the device calibrated against a manufacturer-supplied calibration tile after every set of three measurements. To simulate the clinical surface roughness, the specimens were wet-abraded with 1200-grit silicon carbide discs (400–800 nm thickness; Pudong, Shanghai, China) for the initial color and roughness measurements (E1). The specimens were subsequently divided into two groups based on the polishing method. Group 1 was polished using medium, fine, and superfine Sof-Lex Pop-On discs (3M ESPE, St. Paul, MN, USA), with each disc applied for 15 seconds. Group 2 was polished with Toboom composite resin diamond finishing burs (Toboom, Pudong, Shanghai, China) for 15 seconds, followed by additional polishing with Toboom polishers. After polishing, all specimens were cleaned in distilled water for 10 minutes, and the color (E2) and surface roughness were re-measured. All procedures involving color measurement, including calibration protocols and environmental conditions, were standardized to control for potential colorimetric errors. Following the polishing phase, all specimens were immersed in a tea solution prepared with two tea bags (2×2 g Yellow-Labeled; Lipton, London) steeped in 250 mL of boiling water for 3 minutes. Each specimen was immersed in this solution for 24 days with a daily immersion period of 3 hours. Each specimen was coded and immersed vertically, using a thread for suspension to avoid direct contact with the container walls. To standardize the conditions, the tea solution was refreshed daily.

After the staining period, all specimens were washed with distilled water for 1 minute to remove surface deposits. Color (E3) and roughness were measured post-immersion. All procedures were conducted on only one side of each specimen to control for colorimetric variability, and the reverse side of each specimen was finished with a rough disc after immersion to further minimize potential colorimetric errors.

The polishing/finishing systems used in this study were multi-step Sof-Lex and Toboom mullets.

All the polished specimens were prepared for in-office bleaching after immersion in tea solution and color measurement again (E3) according to the manufacturer's instructions. To perform bleaching, the specimens underwent three sessions every 5 days using 38% hydrogen peroxide gel (Opalescence) for 45 minutes. Every 15 minutes, the gel was washed with water and reapplied. Finally, the specimens were rinsed with distilled water and stored in water to measure their color and surface roughness again (E4). Finally, ΔE was calculated from the magnitude of L*a*and b* parameters [18].

Statistical analysis:

Repeated-measures ANOVA was used to evaluate the effects of bleaching, polishing method, and composite resin type on the surface roughness and color for assessing within-subject factors, such as pre- and post-bleaching measurements, and between-subject factors, including composite resin type and polishing method. Repeated-measures ANOVA was chosen for its effectiveness in analyzing repeated observations on the same specimens under different conditions, providing a robust assessment of the interaction effects and main effects of bleaching and polishing protocols on composite resins. The significance threshold was set at $P<0.05$ using SPSS 24.

Table 1. Composite resins and polishing systems used in this study

Material name	Type of Material	Manufacturer	Composition
Gradia Direct	Composite resin	GC, Japan	Microhybrid composite resin: 60% microfine pre-filler polymer. 85 mm, 20–25% UDMA, 5–10% bis-methacrylate, 1–5% dimethacrylate
Omnichroma	Composite resin	Tokoyama, Japan	UDMA, TEGDMA • Uniform sized supra-nano spherical filler (260 nm spherical SiO_2-ZrO_2) • Composite filler (include 260 nm spherical SiO2-ZrO_2) • Filler loading 79 wt% (68 vol%)
Sof-Lex disc polishing system	Finishing & polishing disc	3M, USA	Polyethylene, synthetic polymers, aluminum oxide and Epoxy resin glue
Toboom mullet	Polishing system	Shanghai Toboom Tech, China	Rubber silicon

Results

Repeated-measures ANOVA was applied to investigate the effects of in-office bleaching on the initial color and roughness variables (E_0), after surface roughening (E_1), after using discs and polishing burs (E_2), after 24 days of immersion in tea solution (E_3), and after performing in-office bleaching (E_4). Table 2 presents the descriptive data on roughness at different time points. The mean roughness increased after roughening the surface of composite resin specimens with silicon discs under clinical conditions. In the next stage, the mean roughness decreased after using discs and polishing burs. In the final stage, the mean roughness increased after bleaching. The interaction effect of composite resin type and finishing method was analyzed first using repeated-measures ANOVA. However, this interaction was not statistically significant for surface roughness ($P>0.05$), indicating that neither the composite type nor the finishing method independently influenced the final roughness outcome post-bleaching.

According to repeated-measures ANOVA, the effect of polishing on the mean roughness change was not significant (P=0.657). Composite resin type did not significantly affect the mean roughness change (P=0.133).

Table 3 shows the mean ΔE values in the groups. As shown in Table 4, type of polishing (P=0.988), type of composite resin (P=0.246), and their interaction (P=0.097) had no significant effect on ΔE_1. Type of polishing (P=0.883), type of composite resin (P=0.580), and their interaction (P=0.148) did not significantly affect ΔE_2. Type of polishing (P=0.094) and their interaction (P=0.063) did not have a significant effect on ΔE_3, while the composite resin type (P=0.021) had a significant effect on ΔE_3. Type of polishing (P=0.229), type of composite resin (P=0.249), and their interaction (P=0.068) had no significant effect on ΔE_4.

Table 2. Descriptive information about surface roughness in 4 stages

Composite			Mean (µm)	Std. deviation
Gradia	After surface roughening	Disc	0.21186	0.125941
		bur	0.26886	0.157456
	After using discs and polishing burs	Disc	0.55029	0.228825
		bur	0.64286	0.182568
	After immersion in the tea solution	Disc	0.32464	0.163452
		bur	0.32707	0.174668
	After performing in-office bleaching	Disc	0.46036	0.187102
		bur	0.45621	0.170573
Omnichroma	After surface roughening	Disc	0.10721	0.062616
		bur	0.10136	0.086906
	After using discs and polishing burs	Disc	0.71121	0.245648
		bur	0.71879	0.298902
	After immersion in the tea solution	Disc	0.28329	0.178704
		bur	0.29914	0.132567
	After performing in-office bleaching	Disc	0.40957	0.206115
		Bur	0.55471	0.167410

Table 3. Mean ΔE values in the groups (n=11)

Composite resin	ΔE	Polishing type	Mean	SD
Gradia	ΔE_1	disk	2.570	1.445
		bur	1.808	1.697
	ΔE_2	Disk	1.887	0.876
		bur	2.657	2.361
	ΔE_3	Disk	13.724	2.320
		bur	11.269	2.875
	ΔE_4	Disk	10.902	2.678
		bur	8.804	2.444
Omnichroma	ΔE_1	Disk	1.268	0.844
		bur	2.044	1.824
	ΔE_2	Disk	2.851	1.035
		bur	2.222	1.573
	ΔE_3	Disk	10.805	1.938
		bur	10.936	1.667
	ΔE_4	Disk	8.839	1.621
		bur	9.282	2.102

SD: Standard deviation

Table 4. Effects of composite type, polishing method, and their interaction on ΔE

Variables	ΔE_1 P-value	ΔE_2 P-value	ΔE_3 P-value	ΔE_4 P-value
Composite type	0.246	0.580	0.021	0.249
Polishing method	0.988	0.883	0.094	0.229
Interaction of composite and polishing	0.097	0.148	0.063	0.068

In the data analysis of ΔLs (where a value closer to 100 indicates a lighter shade, and zero represents black), the relationship between ΔL1 (P=0.403), ΔL3 (P=0.106), and ΔL4 (P=0.408) and the composite resin type, polishing type, and their interaction was not significant. However, the type of composite and the type of polishing had a significant relationship with ΔL2, which represented the period before and after polishing (P=0.018). Omnichroma composite resin was approximately 1.5 units lighter on average (1.03±1.74 vs. 2.70±0.28, P=0.018). Type of polishing significantly influenced the lightness of the composite resins. Additionally, the interaction effect of composite resin type and polishing method on ΔL is presented in Table 5.

The correlation between the composite resin type, polishing method, and their interaction with Δa was not significant (P>0.05) except for the interaction effect of composite resin type and polishing method on Δa_3 (P=0.022) and Δa_4 (P=0.007), indicating that Gradia composite resin and polishing with disc had higher values of Δa (Table 6).

Regarding the Δb data (where yellow represents positive values and blue represents negative values), the results showed a significant effect of composite resin type on Δb at all time points (P<0.05). However, the effect of polishing method and the interaction effect of composite type and polishing method were not significant on Δb at any time point (P>0.05, Table 7).

The color spectrum change from blue to yellow and vice versa was more pronounced in Gradia composite resin compared to Omnichrom.

Discussion

This study examined the effect of in-office bleaching on the surface roughness and color stability of two types of composite resins, Gradia (microhybrid) and Omnichroma (super-nanofilled), polished with different systems. The findings provided valuable insights into the influence of composite composition, filler particle size, and polishing protocols on their performance after bleaching. The following discussion outlines the underlying mechanisms and reasons for these results.

The increase in surface roughness observed in both Gradia and Omnichroma after bleaching can be attributed to the oxidative action of the hydrogen peroxide bleaching agent. Hydrogen peroxide acts by breaking down the organic matrix of the composite resin, especially the resinous phase, which results in surface degradation. This phenomenon is well-documented, where bleaching agents cause resin matrix erosion due to the formation of free radicals and oxidative species that disrupt the polymer chains [4,18]. As a result, the surface becomes rougher as the resin matrix weakens, and filler particles may be exposed or dislodged, depending on their size and bonding to the matrix.

Gradia, as a micro-hybrid composite, contains larger filler particles and a more heterogeneous matrix compared to Omnichroma, which uses supra-nano spherical ZrO_2-SiO_2 fillers. The larger filler size in Gradia results in less homogeneous integration of the resin matrix and filler particles, making the matrix more susceptible to the bleaching agent. As the resin degrades, the larger filler particles in Gradia are more likely to cause surface irregularities, contributing to an increase in roughness after bleaching. In contrast, Omnichroma's supra-nano filler technology allows for a more even distribution of filler particles, leading to better matrix-filler integration and less surface degradation, although some increase in roughness still occurs [19].

Table 5. Effects of composite type, polishing method, and their interaction on ΔL

Variables	ΔL_1 P-value	ΔL_2 P-value	ΔL_3 P-value	ΔL_4 P-value
Composite resin	0.403	0.020	0.106	0.408
Polishing	0.319	0.018	0.173	0.455
The interaction of composite resin and polishing	0.588	0.759	0.061	0.216

Table 6. Effects of composite type, polishing method, and their interaction on Δa

Variables	Δa_1 P-value	Δa_2 P-value	Δa_3 P-value	Δa_4 P-value
Composite resin	0.158	0.096	0.534	0.093
Polishing	0.604	0.365	0.062	0.362
The interaction of composite resin and polishing	0.246	0.116	0.022	0.007

Table 7. Effects of composite type, polishing method, and their interaction on Δb

Variables	Δb_1 P-value	Δb_2 P-value	Δb_3 P-value	Δb_4 P-value
Composite resin	0.000	0.000	0.000	0.022
Polishing	0.608	0.972	0.347	0.237
The interaction of composite resin and polishing	0.200	0.206	0.991	0.118

The interaction between the polishing system and the resin matrix also influenced roughness changes. Polishing with Sof-Lex discs results in a smoother surface compared to diamond bur due to its ability to uniformly abrade both the resin matrix and the filler particles. However, diamond burs, which are harder and more abrasive, may create micro-cracks or uneven wear on the composite surface. After bleaching, these micro-cracks can become more pronounced as the resin matrix deteriorates, exacerbating surface roughness. This effect was observed in both composite resins but may be more significant in Gradia due to its larger filler size and less robust matrix structure [20].

The color stability of composite resins is influenced by both the composition of the resin and the characteristics of the polishing systems. In this study, Gradia exhibited a greater ΔE,

particularly after immersion in tea, turning redder. The reason for this difference in color stability can be attributed to the distinct filler types and the mechanisms of color change of each resin.

Gradia, as a microhybrid composite, contains larger filler particles and pigments that are susceptible to discoloration. During the staining process, such as immersion in tea, the pigments and larger particles in Gradia allow for greater penetration of the coloring agents [21]. The porosity and surface characteristics of Gradia after polishing, especially with diamond burs, may create micro-gaps where pigments can accumulate. These pigments are absorbed more easily by the resin matrix, leading to a noticeably redder hue in Gradia samples after tea immersion. The bleaching process removes some surface stains, but deeper stains embedded in the matrix or filler particles remain, explaining the persistent ΔE [22].

Omnichroma, using structural color technology, avoids the use of added pigments, relying instead on the scattering of light through its supra-nano spherical fillers to create color. This makes Omnichroma less susceptible to surface staining, as the color is generated by the structural arrangement of the filler particles rather than external pigments [23]. As a result, the bleaching process does not affect its color as significantly as in Gradia. The high filler loading (79wt%) and the uniform distribution of ZrO_2-SiO_2 particles in Omnichroma also contribute to its color stability, as these fillers are less likely to absorb staining agents or undergo structural degradation during bleaching [24].

Bleaching agents like hydrogen peroxide work by oxidizing pigmented organic molecules. In Gradia, which contains conventional pigments and larger filler particles, these pigments are more susceptible to oxidative changes, leading to a more pronounced ΔE. In contrast, Omnichroma's reliance on structural color makes it more resistant to bleaching-induced ΔE. This difference explains why Gradia exhibited more ΔE, particularly after immersion in tea, compared to Omnichroma [25].

The polishing systems used in this study had a significant impact on both surface roughness and ΔE. Sof-Lex discs, made of polyethylene and synthetic polymers impregnated with aluminum oxide, produce smoother surfaces because they uniformly abrade both the matrix and filler particles [26]. This results in a smoother finish, which reduces the potential for pigment accumulation and surface irregularities; thus, improving both surface roughness and color stability. In contrast, diamond burs are more abrasive and may cause micro-fractures or uneven wear on the composite surface. This creates a rougher surface that is more susceptible to staining, as the irregularities allow for greater pigment retention. Additionally, after bleaching, these rougher surfaces are more prone to further degradation, leading to an increase in surface roughness [27]. This was particularly evident in Gradia, where the combination of larger filler particles and rougher surfaces created by diamond burs exacerbated the ΔE and surface roughness. The interaction effect of these polishing systems, combined with the differences in resin composition, explain the observed results. Omnichroma, with its smaller filler particles and uniform structure, responded better to polishing and exhibited less roughness and ΔE compared to Gradia. The use of Sof-Lex discs for polishing was generally associated with better outcomes in terms of smoothness and color stability, regardless of the composite resin type [28].

The results of this study demonstrated that both the type of composite resin and the polishing method significantly affected the surface roughness and color stability after bleaching. The following mechanisms can explain these findings:

- **Resin matrix degradation:** Bleaching agents degrade the resin matrix, particularly in composites with larger filler particles like Gradia, leading to increased roughness.
- **Filler particle size and distribution:** Smaller, uniformly distributed filler particles in Omnichroma result in better color stability and less surface roughness after bleaching, as they offer more resistance to oxidative degradation.

Sof-Lex discs create smoother surfaces compared to diamond burs, which reduce the likelihood of pigment absorption and surface degradation; thus, enhancing both color stability and surface smoothness [29].

The main limitation of this study was the lack of simulation of the oral environment in terms of temperature, enzymes, bacteria, occlusion, etc. Future studies are recommended on different types of composite resins with better simulation of the oral environment to obtain more accurate results.

Conclusion

The results showed that the surface roughness of both Gradia and Omnichroma composite resins increased after bleaching. Gradia exhibited more pronounced ΔE, particularly turning redder after immersion in tea, whereas Omnichroma displayed better color stability. These findings suggest that material selection and polishing methods are critical in maintaining esthetic outcomes in bleached composite restorations.

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