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Original Article

Effect of Hydrogen Peroxide Whitening Toothpastes on Color and Surface Properties of Micro-Hybrid Composite Resins: An In Vitro Study

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Abstract
Background: The use of dental composites is widespread, resulting in an inevitable increased demand for esthetic composites because of their aesthetic appeal and high durability. Nonetheless, achieving color stability in composites remains one of the primary challenges. On the other hand, the use of whitening toothpaste may affect the properties of composites. Therefore, the current study aimed to investigate the impact of hydrogen peroxide (H_2O_2)-containing whitening toothpaste on the color change and surface roughness of Extra Bleach, Bleach, and A1 composites.
Methods: This experimental study employed a quantitative research design. Samples of Extra Bleach, Bleach, and A1 composites were divided into 3 groups in a blinded manner. Color changes (ΔE) were measured using a spectrophotometer device, and the roughness of the sample's surface (Ra) was determined using a laser profilometer. The data were analyzed using appropriate statistical tests.
Results: Our results demonstrated a significant difference in surface roughness among the three composite groups. Additionally, this difference was significant between 1A and BW, as well as between 1A and XBW, although there was no significant difference between BW and XBW. The XBW shade revealed the highest surface roughness, while 1A exhibited the smallest increase. Regarding color stability, significant color changes were observed in all three composites. The lowest ΔE belonged to 1A, while the highest ΔE was related to XBW.
Conclusion: It was found that H_2O_2-containing whitening toothpaste increases surface roughness, with a greater increase in Bleach composites. The best color stability was detected in the 1A composite, followed by BW, whereas the least stability was observed in XBW. The findings confirmed that bleach composites have lower strength and color stability compared to the 1A composite.
Keywords: Color change, Composite, Surface roughness, Whitening toothpaste, Hydrogen peroxide

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Background

Nowadays, the widespread use of dental composites has led to an inevitable increase in demand for esthetic composites due to their high durability and aesthetic appeal. With the increasing desire for white and beautiful smiles, the use of whitening toothpastes is also on the rise. Despite significant advancements in dental composites, some challenges remain that require further investigation. One such challenge is assessing the effect of whitening agents on the physical and mechanical properties of dental composites in various shades.

The harmony of hue, chroma, and value in the composite resin, as well as its ability to maintain this harmony over time, is crucial for meeting patients' natural aesthetic demands. The composite's ability to reflect light entering its surface is related to the brightness of the surface and its durability (1).

Improving the physical properties of composite resins, alongside their positive aesthetic aspects, implies that they are now the most widely used direct materials for restoring both anterior teeth and posterior teeth. The roughening of the surface of restorative materials can damage tissues around the teeth and affect the anesthetic features due to plaque accumulation. Evidence indicates that the tongue in the tip section can detect surface variations of 0.3 µ, which can affect the patient's comfort.

Today, brushing with toothpastes specially formulated for whitening is among the frequently applied and cost-effective methods for most patients to achieve whiter teeth and remove stains. Abrasives in whitening toothpastes can effectively remove surface stains from the teeth. However, the cleaning process of teeth is directly related to the hardness, size, shape, and concentration, as well as the composition of toothpaste and the technique of use (2).

The International Standards Organization has established that the abrasion of all toothpastes (i.e., relative dentin abrasion) should not exceed 250 µ, and the relative dentin abrasion for whitening toothpastes must be in the range of 60–100. Toothpaste abrasives vary significantly in composition. Some materials have more abrasivity, and in some cases, whitening toothpastes can cause excessive wear of tooth structure, potentially compromising their effectiveness in cleaning and removing stains (3).

The toothpaste typically contains abrasive materials, including calcium carbonate, calcium phosphate, hydrated silica, calcium pyrophosphate, alumina, perlite, and sodium bicarbonate. Whitening toothpaste, in addition to abrasive materials, also contains chemical whiteners, such as hydrogen peroxide (H_2O_2) and carbamide peroxide (4).

Today, patients need a whiter color and the best match in restorations and composite resins. Therefore, long-term color stability of resin composites is a major criterion of success and one of the most important factors in selecting composites throughout their service life.

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The color changes can be divided into internal or external types. Internal color changes are more permanent because of their diffusion into the material's composition and vary depending on the quality of the polymer, type of filler, and the amount and synergy of the added light-curing initiator. In the oral cavity, color changes in restorations may occur due to surface degradation or the penetration and absorption of staining materials in the deeper layer of composite resins. Additionally, color changes caused by external factors can differ depending on the surface's roughness and integrity, as well as the quality of the polishing techniques (5).

Research has shown that the use of whitening toothpastes containing H_2O_2 can increase the surface roughness of dental composites. This increase in roughness may be attributed to the degradation of the resin matrix and filler particles resulting from oxidation by H_2O_2 (6).

The present study aims to evaluate the whitening effect of toothpaste on the color and surface properties of bleached composites. This area is essential due to the increasing use of bleached composite resins and the limited research on this subject in the dental field.

Materials and Methods

This experimental study was conducted at AJA University of Tehran, Iran, and was approved by the Ethics Committee of AJA University of Tehran, Iran (1403.170. IR.AJAUMS.REC).

Sample Size

The software G*Power (version 3.0.10, Germany) was used to determine the minimum sample size and number, considering an alpha level of 0.05, a study power of 80%, and an effect size of 0.6. The sample size for each composite group was calculated to be 10 samples, totaling 30 samples for each part of this study.

Sample Preparation

In this study, 60 disk-shaped molds were required to create composite discs with diameters of 10 mm and 2 mm.

Composite molds were prepared through consultation with the Light and Color Laboratory at the CNC Design Center. The samples were prepared using a layering technique with a thickness of 2 mm, with glass slips placed on both sides of the surfaces. Curing was performed for 30 seconds using an LED Kerr light-curing device (Kerr, Collins Ave., USA) with a wavelength range of 420–480 nm and an output intensity of 850–1600 mW/cm^2). To calibrate the intensity of the light-curing unit, a radiometer was utilized every five specimens. Curing continued after calibration. The compositions and manufactural use of resin composites are provided in Table 1.

A total of 60 samples of 3 types of micro-hybrid resin composites (2 × 10 mm^2) were prepared (A1, Bleach, and Extra Bleach) using blocks (Figure 1). Composite disks were polished and ground with 400, 600, 800, 1000, and 1200 grit silicon carbide abrasive papers (Gripo 2

Table 1. Composition and Manufacture of Dental Resin Composites

Type	Material	Manufacturer	Composition
Block	Carizma A1	Kulzer, Germany	Barium aluminium Boro Fluorsilicate, silica, UDMA, TCD, TEGDMA, titanium dioxide, Metallic oxide pigments, organic pigments, Aminobenzoic acid ester, and a camphorquinone
Block	Carizma Bleach	Kulzer, Germany	Barium Aluminium Boro Fluorsilicate, silica, UDMA, TCD, TEGDMA, and titanium dioxide
Block	Carizma Extra Bleach	Kulzer, Germany	Metallic oxide pigments, Organic pigments, aminobenzoic acid ester, and camphorquinone
Toothpaste	Colgate Optic White	Colgate-Palmolive Company	Sodium Monofluorophosphate (0.76% (0.13% w/v Fluoride Ion)). Purpose: Anticavity. Inactive Ingredients: Propylene Glycol, Calcium Pyrophosphate, Glycerin, PEG/PPG-116/66 Copolymer, PEG-12, PVP, Silica, Flavor, Sodium Lauryl Sulfate, Tetrasodium Pyrophosphate, Hydrogen Peroxide, Disodium Pyrophosphate, Sodium Saccharin, Sucralose, and BHT

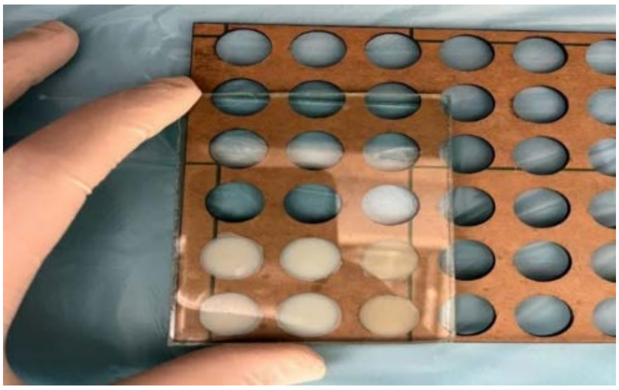

Figure 1. Preparation of Composite Molds

V, Metkon, Bursa, Turkey) using an angle handpiece at 15,000 rpm. An ultrasonic cleaner was used to clean the specimens (Codyson Ultrasonic Cleaner CD-4831). Then, the specimens were dried at room temperature for 30 seconds. A digital caliper (Alpha Tools, Mannheim, Germany) was employed to check the final thickness of the disks. Afterward, the samples were immersed in an artificial saliva solution (with a composition of KH_2PO_4, Na_2HPO_4, KCl, NaSCN, NaCl, $CaCl_2$, NH_4Cl, urea, and distilled water) in an incubator at 37°C for 48 hours. (7) A thermocycling process simulating oral conditions was performed before any measurements. All samples were kept in a water bath for 20 seconds and 5 seconds interval, and 500 cycles were performed at 5–55 °C.

Next, all the samples were divided into two groups, and this separation was performed in a blinded manner. Each sample was numbered randomly, and each sample had a unique number to ensure that, at each stage, comparisons were made only with itself (Figure 1).

In this research, an attempt was made to standardize composite discs for evaluating the effect of brushing with H_2O_2 whitening toothpaste on the surface roughness and color stability of Bleach, Extra Bleach, and A1 composites. To this end, a total of 30 samples of discs (n = 10 for each composite) were prepared (Table 1).

The degree of conversion (DC) is a crucial factor in determining curing accuracy and color change in photo-activated composite resins. Accordingly, the DC of all specimen types is measured before commencing measurements, ensuring consistency across different curing units. The proportion of the carbon double bonds C = C in the cured composite sample relative to the total number of carbon bonds C = C in the composites before curing is referred to as DC (8). In this study, DC measurements were made using infrared spectroscopy.

The DC% obtained from different shades of microhybrid dental composites is presented in Table 2. Based on the results, there were no significant differences in DC among different shades of composites.

Composite disks were immersed in the coffee solution (30 g in 600 mL of Nescafé Gold Swiss at 37 °C) for 14 days. To prepare the coffee solution, 1 tsp of soluble coffee was dissolved in 300 mL of boiling water. Then, assuming an average adult has at least 28 teeth, brushing for 120 seconds twice a day resulted in 56 brushing locations, including buccal, lingual, and occlusal surfaces. Therefore, our simulation time was 5 seconds per day for each surface. In other words, each sample was brushed for a total of 450 seconds to simulate three months of brushing. In this study, the brushing process was performed using the Dentarg brushing simulator (Analitik Medikal, Turkey) through the horizontal brushing technique.

Table 2. The Mean of DC in Resin Composite Samples

Dental composite	Shade of composite	Mean	SD	*P* value
Micro-hybrid resin	Extra bleach	67.18	1.00	0.878
	Bleach	68.37	1.00	
	A1	68.98	1.00	

Note. DC: Degree of conversion; SD: Standard deviation.

Color Measurement

For color measurement, the spectral reflectance of the samples was recorded, and then the color coordinates of the samples were calculated. To ensure more accurate results, three measurements (from the middle part of each sample) were taken at each stage for each sample, and the average of these measurements was used and considered in the results for each sample. The tests for color measurement and roughness analysis of the surfaces for each sample were performed by a single investigator who had received careful training.

Initial color measurements of all specimens were made using a VITA spectrophotometer (Zahnfabrik, Germany) to measure the CIE L*a*b* color system. A grey background was utilized to measure the distance from the center of each specimen in the perpendicular direction of the sample surface. Before each measurement step, the white calibration plate was employed in the spectrophotometer and calibrated according to the manufacturer's instructions. In each test, every sample was measured in triplicate to minimize potential variations in measurements, and the average of these measurements was calculated. After applying the brushing technique, the final color values were measured again using the same method.

The samples were evaluated once before and once after being brushed with whitening toothpaste containing H_2O_2. Afterward, the data were analyzed and examined.

Roughness Measurement

Initial surface roughness measurements were performed using a contact profilometer (Surtronic 25, Taylor Hobson, Leicester, UK), with an extent of 4 mm, a cut-off length of 0.8 mm, and a stylus speed of 1 mm/s, and then recorded in μm. First, the profilometer was calibrated, and roughness tests were conducted in three-point areas of the sample surfaces. The average of the three tests was recorded as the initial roughness value. Following the same principles after the brushing process, the surface roughness values (Ra1) of the samples were recorded as the final Ra (Figure 2). A single operator performed the measurements.

Results

Based on numerical results, the use of whitening toothpaste significantly increased surface roughness in all cases. The most surface roughness increase was observed in Extra Bleach composites, while the least increase was related to A1 composites. This increase was also examined through pairwise comparisons, demonstrating significant differences in all cases, except for the surface roughness increase in Bleach and Extra Bleach composites ($P=0.13$, Figure 3).

The highest and lowest surface color changes belonged to the Extra Bleach composites and A1 composites, respectively. This increase was also investigated through pairwise comparisons, representing statistically significant differences in all cases (Figure 4).

Finally, the greatest changes in both color and surface roughness were observed in the Extra Bleach composites, followed by the Bleach composites, with the least changes occurring in the A1 composites. In all cases, there was an increase in surface roughness, while the A1 composites exhibited the highest color stability (Tables 3 and 4).

Tables 3 and 4 present a summary of the statistical data for the D.E. (color change) and D.Ra (surface roughness) measurements of the three composite materials (A1, BW, and XBW).

Discussion

Today, tooth bleaching is one of the most common dental services. People are increasingly concerned with their appearance, and tooth discoloration can significantly impact self-confidence, leading to discomfort and psychological distress. The variety of teeth whitening products has noticeably increased with the increasing aesthetic expectations and the search for solutions to alter the color of teeth. Whitening toothpastes have a considerable effect on surface roughness and color change in restorations compared to regular toothpastes.

As previously mentioned, this study examined the color change and surface roughness of micro-hybrid composites (Kulzer). One of the whitening toothpastes containing H_2O_2 in the world (Optic White Colgate) was used for this purpose. Coffee was chosen as a staining solution because it causes significant color changes in restorative materials, in addition to being one of the most popular beverages globally (9).

Coffee not only causes surface staining but also can result in subsurface stains due to its polar coloring compounds and their delayed absorption by the resin composite surface. Furthermore, it has been reported that higher ambient temperatures can accelerate the color change of restorative materials. Therefore, composite resin samples were maintained at 37 °C, simulating the oral environment.

Based on the results, the null hypothesis of this study

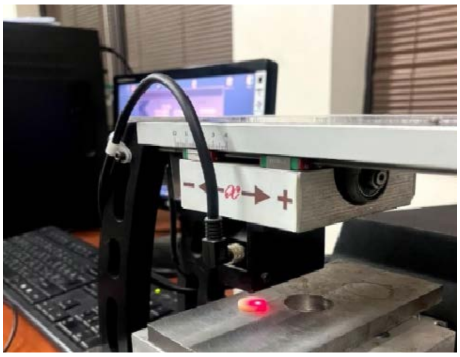

Figure 2. Surface Roughness Laser Check

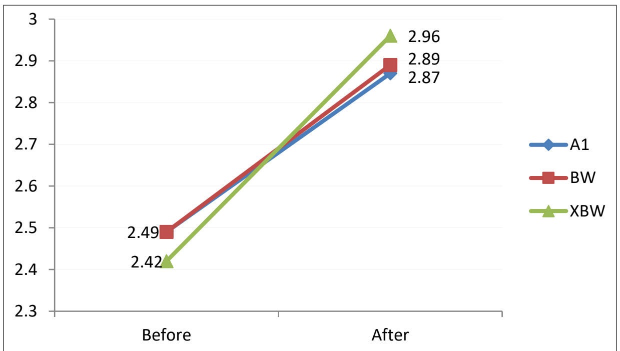

Figure 3. Examination of Surface Roughness Changes

Table 3. Statistical Analysis of Resin Composites (Color Changes)

D.E.	Standard Deviation	Mean	*P*-Value
A1	0.3985	2.41	
BW	0.3107	3.69	$P<0.001$
XBW	0.4671	4.66	

Note. The *P* value indicates the statistical significance of the differences observed among the composites.

Table 4. Statistical Analysis of Resin Composites (Surface Roughness Changes)

D.Ra	Standard Deviation	Mean	*P*-Value
A1	0.125345	0.3236	
BW	0.17872	0.4857	$P<0.004$
XBW	0.184959	0.5947	

Note. The *P* value indicates the statistical significance of the differences observed among the composites.

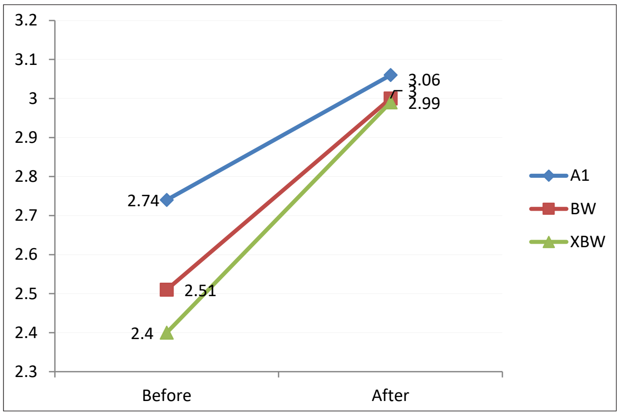

Figure 4. Examination of Color Changes

(i.e., whitening toothpaste containing H_2O_2 does not affect the color and surface roughness) was rejected due to the varying degrees of color change and increased surface roughness observed after using whitening toothpaste on restorative materials.

In this study, surface roughness increased in all groups after brushing, which is consistent with the results of previous research by Dos Santos et al. (10) Different resin composite shades are obtained by adding small amounts of inorganic metal oxide pigments. The most common pigments used to create shade A are iron oxides. In contrast, titanium dioxide pigments are considered one of the best whitening pigments in bleached composites due to their excellent properties, including whiteness, high brightness, non-toxicity, and high opacity (11).

Da Silva Fontes et al analyzed the impact of pigment amounts and opacifying components on the polymerization and mechanical properties of two Brazilian dental composite brands. The researchers found that composites with higher opacity have lower polymerization (conversion degree) and weaker mechanical characteristics compared to those with less opacity. They attributed this issue to the impact of pigment levels and opacifying components, as these materials reduce the light intensity required for the polymerization initiator process. According to this study, a composite has lower physical strength and properties when its pigment content is higher, regardless of the type of pigment. This result may explain the lower roughness changes in the Bleach composite compared to the A1 composite (12), which is in line with our findings.

Thus, bleached composites (i.e., BW and XBW) have higher opacity due to higher amounts of pigments (especially the use of titanium dioxide for whitening) compared to the A1 composite. This higher opacity, which prevents light transmission, leads to a shallower cure depth, reduced polymerization degree, and overall lower polymerization quality in the composites, resulting in structural weakness.

The color stability of composite resin restorations is one of the most important factors affecting their long-term success (13). The color change of composite resins can cause patient dissatisfaction and, in the long term, lead to treatment failure (14). Therefore, the resistance of composite restorative materials to color change, which are primarily used in aesthetic areas, is crucial (15).

Despite significant advances in the development of dental composites, color change remains a major concern. Composite restorations undergo color changes in the oral environment, but the extent of this change is the important issue. When ΔE is less than or equal to 1, it is not perceptible to the human eye. However, the color change is noticeable to an experienced examiner when ΔE is between 1 and 3. Moreover, when ΔE is greater than or equal to 3.3, the color change is considered clinically significant (16).

Color change in dental composites may be due to internal factors related to the composite structure or external factors, such as diet or idiopathic causes. Foods or dietary habits (e.g., consuming tea, coffee, soft drinks, certain medications, mouthwashes such as chlorhexidine, or nicotine) can affect the appearance of composites by causing discoloration. Coffee consumption, in particular, cause color changes in composites.

Composite restorations change color when exposed to colored compounds, and the degree of color uptake depends on several factors. Surface roughness (Ra) can affect the ability of a material to absorb color (17). The resin-filler interface is one of the weakest points in the composite material and is highly sensitive to water absorption. Water absorption in this area can lead to microcracks and gaps between the filler and resin matrix, providing a pathway for colorant penetration (18).

The DC can also affect color stability and depends on various factors, including the light intensity and wavelength of the light-curing device, curing time, composite color, translucency, opacity, and material thickness. A reduced DC results in lower mechanical properties, increased water absorption, and reduced color stability (19).

Based on our results, the lowest color change was observed in the A1 composite, while the greatest change was noted in the XBW composite. The color change between these two composites was most pronounced in the BW composite. Considering that factors influencing color stability are the same across the three composite shades (based on the manufacturer's catalog, including filler type, filler amount, and resin type), the degree of polymerization (conversion degree) may differ between shades of the same composite brand. The explanation is that A1 composite has a lower opacity compared to bleached composites, allowing for more light transmission and resulting in a higher DC. This result confirms the better color stability of A1. However, bleached composites (i.e., BW and XBW) exhibit higher opacity, resulting in a lower DC and greater water absorption. As a result, they increased pigment absorption, ultimately leading to a more pronounced color change.

Emami Arjomand et al, investigating the effect of aging on color stability in Bleach shade composites, found that composites with higher translucency (lower opacity) typically display better curing efficiency and higher degrees of conversion, resulting in greater color stability (20), which corroborates our findings.

Additionally, various factors, including polymer matrix composition, filler particle type, DC, and environmental conditions, can influence the solubility and water absorption of composites. It can be concluded that lower degrees of conversion result in higher solubility and water absorption. These findings support our conclusion that XBW composites exhibit the greatest color change due to a lower DC compared to the other shades, leading to greater water absorption and increased pigment uptake (21).

The effect of shade and light curing distance on the

DC was investigated, revealing that composite materials in blue shades demonstrated the highest DC. In contrast, those in white shades showed the lowest DC (22), which conforms to our results.

Conclusion

Our findings confirmed that H_2O_2 whitening toothpaste increased surface roughness in all groups, with the greatest increase observed in the Bleach composites. Additionally, the whitening toothpaste caused the most significant color change in the XBW composites. As a result, the best color stability was found in A1 composites, followed by the BW composites, with the poorest color stability detected in the XBW composites. For more accurate results, it is recommended that future studies focus on surface characteristics with a scanning electron microscope.

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Authors' Contribution

Conceptualization: Elnaz Shafigh.
Data curation: Saeed Ghasemi.
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Investigation: Elnaz Shafigh.
Methodology: Elnaz Shafigh.
Project administration: Elnaz Shafigh.
Resources: Siavash Abdollahpoor.
Software: Siavash Abdollahpoor.
Supervision: Elnaz Shafigh.
Validation: Elnaz Shafigh.
Visualization: Saeed Ghasemi.
Writing – original draft: Saeed Ghasemi.

Competing Interests

The authors declare no conflict of interests.

Consent for Publication

All authors have consent for publication and have declared this issue in the consent form.

Data Availability Statement

The databases and findings of this study are available upon reasonable request from the corresponding author. The data are not publicly available because of ethical restrictions.

Ethical Approval

The protocol of the present research was approved by the Ethics Committee AJA University of Tehran (IR.AJAUMS.REC.1403.170). By this code, it was unnecessary to obtain consent from participants.

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