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Assessment of Surface Roughness and Compressive Strength of Resin-Based Composite Using Different Types of Bleaching Protocols

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Abstract: This study aims to assess surface roughness and compressive strength of resin-based composite using different types of bleaching protocols. Three different bleaching protocols were applied to determine their effect on composite resin's compressive strength and surface roughness. Eighty composite resin samples were prepared using metal molds; forty samples (2 mm in height and 8 mm in diameter) for surface roughness evaluation and the other forty samples (6 mm in height and 4 mm in diameter) for compressive strength. Every forty samples were divided into four groups. In group 1 (n = 10), samples were stored in deionized water at 37°C for two weeks as control, in group 2 (n =10), samples were subjected to home bleaching with 22% carbamide peroxide (CP), in group 3 (n = 10) samples were subjected to home bleaching with 14% hydrogen peroxide (HP), and in group 4 (n =10) samples were subjected to bleaching with 25% hydrogen peroxide (HP in-Office) in a dental clinic. After bleaching, surface roughness and compressive strength of groups 2, 3, and 4 were measured. After applying bleaching protocols, a similar increase in the enamel surface roughness of all samples was observed; however, this increase was not statistically significant compared to the control group. The CP-treated group had the highest surface roughness. All three bleaching protocols resulted in a decrease of compressive strength of the composite compared to the control group, and the minimum compressive strength belonged to the HP-treated group, followed by HP in-Office group and CP group, respectively. According to the results of this study, there was an increase in surface roughness using different types of bleaching protocols (22% CP and 14% HP) at-Home bleaching technique and (25%) in-Office HP bleaching with no significant difference between them, while all three bleaching protocols reduced the compressive strength of the composite with no significant difference.

Keywords: bleaching protocol, hydrogen peroxide, carbamide peroxide.

使用不同類型的漂白方案評估樹脂基複合材料的表面粗糙度和抗壓強度

摘要：本研究旨在使用不同類型的漂白方案評估樹脂基複合材料的表面粗糙度和抗壓強度。應用三種不同的漂白方案來確定它們對複合樹脂的抗壓強度和表面粗糙度的影響。使用金屬模具製備了80個複合樹脂樣品；四十個樣品（高二毫米，直徑八毫米）用於表面粗糙度評估，另外四十個樣品（高六毫米，直徑四毫米）用於抗壓強度。每四十個樣品被分成四組。在第一 組（數字 = 十）中，樣品在 37°C 的去離子水中儲存兩周作為對照，在第二組（數字 = 十）中，樣品用 22% 過氧化脲進行家庭漂白，在第三 組 (數字 = 十) 的樣品使用 14% 過氧化氫進行家庭漂白，第四 組 (數字 = 十) 的樣品使用 25% 過氧化氫(過氧化氫在辦公室)進行牙科漂白診所。漂白後，測量第二、三和四組的表面粗糙度和抗壓強度。應用漂白方案後，觀察到所有樣品的牙釉質表面粗糙度都有類似的增加；然而，與對照組相比，這種增加沒有統計學意義。過氧化脲處理組具有最高的表面粗糙度。與對照組相比，所有三種漂白方案均導致複合材料的抗壓強度降低，最小抗壓強度屬於過氧化氫在辦公室處理組，其次是過氧化氫在辦公室辦公室組和過氧化脲組。根據這項研究的結果，使用不同類型的漂白方案（22%過氧化脲和14%過氧化氫）在家漂白技術和(25%)在辦公室過氧化氫漂白，表面粗糙度有所增加，兩者之間沒有顯著差異它們，而所有三種漂白方案都降低了複合材料的抗壓強度，但沒有顯著差異。

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关键词：漂白協議，過氧化氫，過氧化脲。

1. Introduction

The accomplishment of full esthetic restorations is the most stressful procedure that is concerned by dentists. Although there are different techniques for esthetics enhancement, bleaching is very promising for treating discolored teeth due to its safety, conservativity, low cost, and efficiency. Numerous bleaching agents have been marketed, but the commonly used active ingredient is carbamide peroxide (CP) [1].

Vital and nonvital tooth bleaching has a long and successful history [2]. Bleaching treatment presents in the forms of at-home or in-office bleaching using carbamide peroxide (CP) and hydrogen peroxide (HP), respectively. About 15% CP is the most commonly used bleaching agent for at-home bleaching, while HP is the most effective for removing internal stains in the office setting [3]. It has been noted that tooth bleaching is relatively safe regarding potential alteration in tooth structure. However, some concerns still exist regarding the adverse effects of bleaching agents on restorative materials and their adhesion to dental tissues [4, 5]. Restorative filling materials which are used in dentistry must have long-term durability in the oral cavity. In order to determine the resistance of restorative materials against masticatory forces, it is required to determine the compressive strength values of the restorative materials it is necessary to determine the resistance of restorative materials against masticatory forces [6]. Several investigators have studied the effects of home bleaching on restorative materials and oral tissues [7]. There are several types of bleaching methods, including nonvital bleaching, at-home bleaching, and in-office professional bleaching. The level of whitening agent in Nightguard home bleaching is relatively low, and it is worn at night using a custom-fabricated mouthguard for at least two weeks. According to the previous research, bleaching agents, regardless of the type of whitening products, hinder the microhardness of the enamel and increase the surface roughness [8].

This study sought to assess the effect of different tooth bleaching protocols using 22% CP, 14% HP at-Home bleaching, and 25% HP in-Office bleaching activated by light on the surface roughness and the composite resin compressive strength.

2. Materials and Methods

2.1. In Vitro Study

In the in vitro study, A2 shade Charisma Diamond nano-hybrid filler (CHARISMA, Kulzer, GmbH, Germany) (Fig. 1) was used to fabricate 80 samples for both surface roughness (2 mm in height and 8 mm in diameter) and compressive strength (6 mm in height, and 4 mm in diameter) [9].

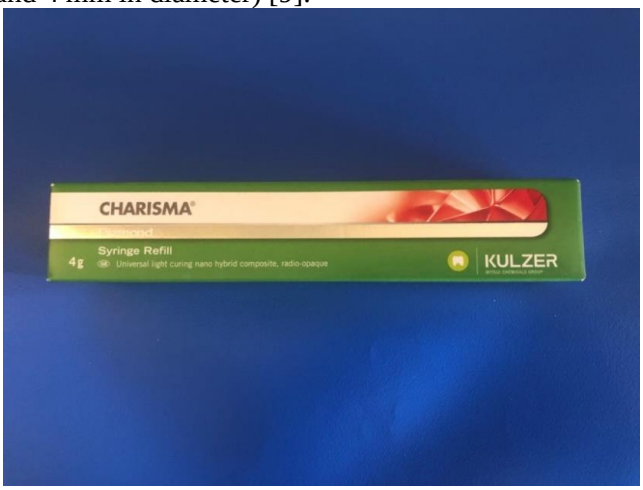

Fig. 1 Charisma Diamond composite resin used in the study

After fabrication and polishing, the samples were immersed in the deionizing solution to ultrasonically remove the residues and were then randomly divided into four groups (n = 10) as follows:

- Group 1: The samples were stored in deionized water at 37 °C for two weeks as the control
- Group 2: The samples were subjected to bleaching with 22% Carbamide Peroxide (CP) (Flash, Take-Home Whitening System, WHITEsmile, Germany) for 1-4 h a day for a total of 10 days according to manufacturer instructions (Fig. 2).
- Group 3: The samples were subjected to bleaching with 14% Hydrogen Peroxide (HP) (Philips Zoom Day White, Discus Dental, USA) recommended by the manufacturer every 3–5 days for 30 min for a total of 2 weeks (Fig. 3).

Group 4: The samples were subjected to bleaching with 25% Hydrogen Peroxide (HP in-Office) in the dental clinic (Philips Zoom, Chair Side Light-Activated Whitening Gel, Discus Dental, Ontario, CA, USA) activated by light using PHILIPS ADVANCED ZOOM LED Curing and Whitening System (Discus Dental, USA) for 40 min according to the manufacturer's instructions (Fig. 4).

Fig. 2 22% Carbamide Peroxide, Flash, Take-Home Whitening System, WHITEsmile Home Bleaching

Fig. 3 14% Hydrogen Peroxide Philips Zoom Day White, Discus Dental Home Bleaching

Fig. 4 25% HP Philips Zoom Day White, Discus Dental in-Office Professional Bleaching

Table 1 represents the details of the chemical composition of the used bleaching materials.

Table 1 Chemical composition of the bleaching materials

Bleaching material	Composition
Take-Home Whitening System (CP)	Glycerin, Hydrogen carbamide 22%, Carbomer, Tromethamine, Disodium pyrophosphate, Aroma
Philips Zoom Day White (HP)	Water, Glycerin, Hydrogen peroxide 14%, Propylene, Potassium nitrate, Eugenol, Phosphoric acid
Philips Zoom, Chair Sidelight Activated Whitening Gel (HP in-Office)	Water, Poloxomer 407, Glycerin, Hydrogen peroxide 25%, Propylene Glycol, Potassium Hydroxide, Eugenol, Ferrous Gluconate.

Samples were cleaned with a soft toothbrush and deionized water for 1 min to eliminate the tooth surfaces' bleaching agents. This was performed daily after bleaching in Group 2, after each bleaching cycle in Group 3, and after completing the bleaching process in Group 4.

2.2. Surface Roughness

Ten samples for each group were prepared by filling the cylinder cavities (with an inner diameter of 8mm and a height of 2 mm) with composite resin [10]. Cylindrical cavities were created at the center of the self-cured acrylic resin block by pouring the resin in a plastic tube with 2 cm in diameter and 2.5 cm in height [11] (Fig. 5).

Fig. 5 Preparation of the cavity mold for roughness testing

The composite resin was packed directly against the cavity with an Ash plastic instrument in 2 mm thickness, which is the thickness of the cavity. Then, the surface of the cavity was covered with a polyester matrix strip and microscopic glass slide to make sure that there was a uniform distribution of the materials and avoid air entrapment and flush out any excess material [12]. Polymerization of each material was performed by a blue phase C8 light cure.

The specimens were first rinsed with water spray for 15 seconds and then dried with oil-free air spray for 15 seconds. Specimen were finally ultrasonically cleaned in deionized water for ten minutes to remove debris and incubated in deionized water at 37°C for 24 hours [13].

The specimens were dried with white filter paper, labeled according to the material categories, encoded, and prepared for surface roughness. A surface profilometer was used to measure and record the surface roughness. The most commonly used instrument was a diamond stylus, which travels straight along the resin surface. The average surface roughness for the composite surface sample was expressed as Ra (μm) value, Fig. (6).

Fig. 6 Taylor Hobson Roughness Profilometer device and Ra reader

The cut-off value (distance transverse by the stylus over which the data were collected) for surface roughness was set at 0.25 mm, and the needle speed was kept constant at 0.5 mm/s, and measuring the length of 1.5 mm, the radius of the tracing diamond tip was 2μm. The data were read three times for each specimen (Fig. 7). The average of these three measurements was reported as the value for each specimen [14].

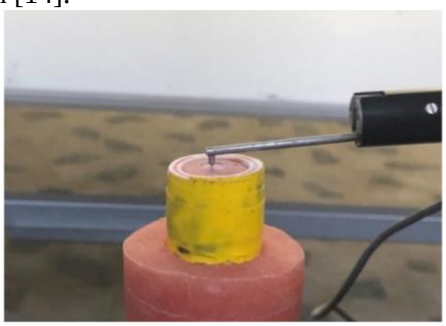

Fig. 7 Surface roughness testing by using Taylor Hobson profilometer head

In order to ensure the reliability of the data, the machine was calibrated after every three specimens by calibration block with an exact value of the surface roughness 1.64 μm (Fig. 8).

Fig. 8 Calibration of the profilometer by using 1.64 μm block

2.3. Compressive Strength

A split metal mold coated with an appropriate separating medium was fabricated to prepare a cylindrical specimen of 4.0 ± 0.1 mm diameter 6.0 ± 0.1 mm height. Ten specimens from each material were used for the compressive strength experiment. The mold was covered with vaseline before applying materials; a Mylar matrix strip was first mounted on a glass slide to form the base of the mold, then filled with composite, which was added incrementally up to 2 mm thickness. Then the materials were light-cured using a Bluephase C8 LED lamp (Ivoclar Vivadent) with a curing light of 800 mW/cm^2 intensity for 20 seconds. The intensity of the curing light was checked by a radiometer (Ivoclar Vivadent) before curing each specimen. Another strip and glass microscopic slide were used to cover the materials; then, the pressure was applied to expel excess material from the mold. Each specimen was light-cured through the top of the glass slide for 40 seconds. After finishing irradiation, the specimens were cleaned to remove the excess materials using a plastic spatula (to avoid contamination with metallic particles). The specimens were visually inspected for detection of voids and irregularities, in which if it was detected, the specimen was discarded and replaced by another one. Each specimen was transferred to plastic test tubes containing 3 ml of deionized water and kept for 24 hours. All specimens were incubated at 37 °C for 24 hours before they were subjected to compressive load. After incubation, they were dried with a sheet of white filter paper. The compressive strength was measured via the universal testing machine with 1 mm/min crosshead speed (Fig. 9) [9].

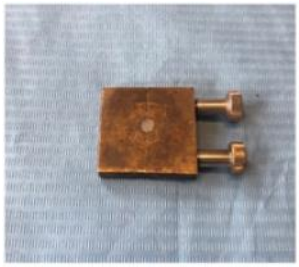

Fig. 9 Compressive strength test procedure: (A) Cylindrical metal mold filled with tested materials, (B) Specimen of 4.0 mm diameter and 6.0 mm height, (C) Universal testing machine, (D) Specimen before load application

The analysis of compressive strength has been done by recording the maximum failure load for each specimen and divided by the net cross-sectional area to determine the compressive stress (K) in MPa by this equation [15], [16]:

$K = 4F/\pi d2$

where F is maximum applied load in Newton, d is the mean diameter of the specimen in mm.

2.4. Statistical Analysis

The obtained data were analyzed using SPSS16 by Post Hoc test. $P < 0.05$ was considered significant in all statistical analyses (Least Statistical Difference LSD).

3. Results

As apparent from the results that are shown in table (2), there was no significant difference between all the bleaching groups with the control group, although there was an increase in the surface roughness values after using different bleaching protocols, and the highest value was recorded in Carbamide Peroxide group (0.68 µm) as shown in Fig. 10.

Table 2 Post hoc test (LSD) of enamel roughness (µm) after bleaching protocols

Compressive Strength (MPa)					
Groups	**NO**	**Mean**	**±SD**	**SE**	**P***
Control	10	200.48	37.65	11.9	0.264
CP	10	185	45.72	14.46	0.387
HP	10	171.8	38.85	12.28	0.113
HP in-office	10	181.6	34.78	10.99	0.294
Total	40	184.7	39.32	12.40	

* Statistically significant $P < 0.05$

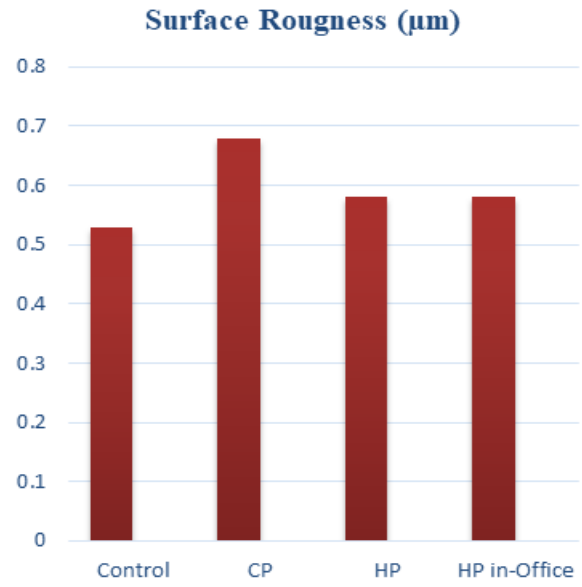

Fig. 10 Bar chart of surface roughness of all groups

The compressive strength of the composite was decreased after using bleaching protocols in all groups in comparison with a control group (200.48 MPa), and the minimum compressive strength was obtained for the HP group followed by the Prof group and CP group, respectively (171.8 MPa, 181.6 MPa and 185 MPa) (Fig. 11).

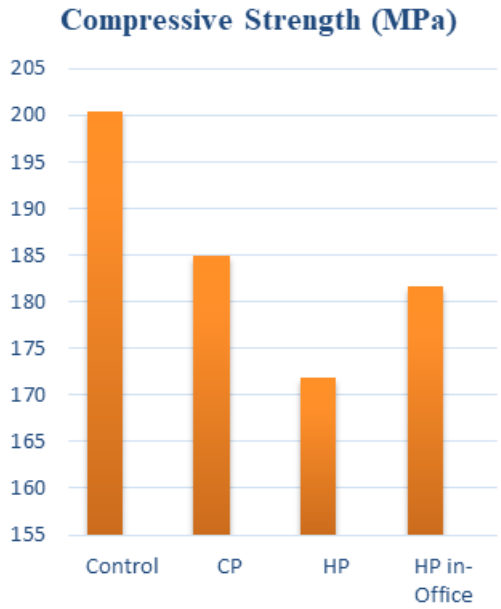

Fig. 11 Bar chart of compressive strength of all groups

Although the compressive strength of samples in bleaching groups was less than that of the control group, the difference was not statistically significant, as illustrated in Table 3.

Table 3 Post hoc test (LSD) of compressive strength (MPa) after bleaching protocols

Compressive Strength (MPa)					
Groups	**NO**	**Mean**	**±SD**	**SE**	**P***

Continuation of Table 3					
Control	10	200.48	37.65	11.9	0.264
CP	10	185	45.72	14.46	0.387
HP	10	171.8	38.85	12.28	0.113
HP in-office	10	181.6	34.78	10.99	0.294
Total	40	184.7	39.32	12.40	

* Statistically significant P < 0.05

4. Discussion

Surface roughness (Ra) refers to the finer irregularities of the surface texture, and its value is within micrometer size. Ra is a property affected by the interaction of many factors. Some of these factors are intrinsic properties of the material which depend on its composition, such as size, shape, filler type, and distribution, the type of resin matrix, the degree of curing, and the bonding strength at the filler/matrix interface. Extrinsic factors are affected by the type of polishing system, such as the flexibility of the abrasives incorporated material, abrasive hardness, the instruments' geometry, and how they are used [17], [18].

The resistance to fracture within a restorative material is specified by fracture stress, which is often referred to as the materials' strength. Compressive strength is another important characteristic of restorative materials, particularly in the mastication process. It is well known that the mechanical characteristics of the fissure sealant are strongly associated with the filler content, filler distribution, particle size, and particle type. Bonding between filler and matrix is also a factor that affects mechanical properties, including strength and modulus of elasticity [19], [20].

The current study assessed the effect of different bleaching protocols using bleaching materials with different compositions and structures on resin-based composite surface roughness and compressive strength.

Degradation of the surface of composite resins might lead to abrasion, surface roughness, and discoloration of restorations. An increase in the surface roughness may lead to gingivitis and periodontal problems through an increase in plaque accumulation [21].

In the present study, the effect of three different bleaching protocols (22% CP and 14% HP as at-Home bleaching techniques and 25% in-Office professional HP bleaching) on the surface roughness of composite resin was evaluated. Although no statistical difference was observed between all groups in a matter of surface roughness, it has been noted that the surface roughness was increased after bleaching when compared with the control group.

The increase in surface roughness after bleaching can be explained by previous studies, which revealed that peroxide bleaching gels might lead to slight roughness of resin-based composites although, it may have no clinical significance. It has been found that bleaching agents impair surface integrity, affecting the penetration depth of bleaching agents. Chemical softening from bleaching may affect the clinical longevity of the composite restoration [22].

The present study revealed that composite tested underwent superficial surface alterations after bleaching. Interestingly, some studies have reported an increase [23], decrease [24] or unchanged [25] composite surfaces after applying carbamide peroxide gels for varying periods. The authors suggested that the complex interactions between the different components of bleaching products could cause changes in surface morphology. The enhancement of surface roughness could be due to the loss of matrix rather than filler particles. Some aspects of this chemical process might accelerate hydrolytic degradation of resin composites, according to Söderholm [26]. Another reason may be the influence of hydrogen peroxide and free radicals on the resin-filler interface, which can cause their debonding, resulting in the formation of microscopic cracks and an increase in surface roughness [27].

Free radicals produced by the peroxides may affect the resin–filler interface and cause filler–matrix detachment. In other words, free radicals eventually form water and accelerate the hydrolytic degradation of composite resins. The latter can also cause bond failure between the resin matrix and filler particles and lead to separation and debonding of filler particles, which further increases the surface roughness of composite resin [28].

It was reported that 6% HP had no significant effect on the surface morphology of composite resins [26]. Wattanapayungkul et al. only found insignificant differences in surface roughness between the control and bleached groups [27].

However, some research indicated that 10% and 16% CP could cause a significant increase in the surface roughness and porosity of hybrid and micro-filled composite resins [29]. Carbamide peroxide (at-Home bleaching) degradation produces urea and hydrogen peroxide. Then, hydrogen peroxide breaks down into free radicals, which eventually produce molecular oxygen and water. Some stage of this chemical process could induce the accelerated hydrolytic degradation of tooth-colored restorative materials [25].

The compressive strength was decreased after using bleaching protocols, although there was no statistical difference between all groups seen in the present study. The possible explanation for the reduction in the compressive strength might be the presence of the Bis-GMA monomer. Resin composites containing Bis-GMA monomer are highly susceptible to chemical softening if the solubility of chemicals ranges from 1.82 × 104 to 2.97 × 104 (J/m3). Another reason could be the bonding degree of the filler to the resin matrix.

The negative effect of oxidative bleaching agents on the resin matrix through water sorption of the

restorative material and relative or complete debonding of the fillers is still a matter of controversy; this factor might decrease the surface integrity and hardness of the material.

5. Conclusion

The present study evaluated the effect of three different bleaching protocols on composite resin's surface roughness and compressive strength.

All bleaching protocols (22% CP and 14% HP at-Home bleaching technique and 25% in-Office HP bleaching) resulted in decreased surface roughness and compressive strength of the composite resin. However, the changes were not statistically significant.

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