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Role Of Charcoal In Whitening Toothpastes On Surface Roughness And Color Stability Of Coffee Stained Nanohybrid Composite Resin: An In Vitro Study

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Abstract

Background: The increasing demand for esthetic dentistry has led to the widespread use of whitening toothpastes, particularly those containing activated charcoal. Although these dentifrices are marketed for stain removal and whitening, their abrasive nature may adversely affect restorative materials such as composite resins, causing surface roughness and discoloration.

Aims and objectives: Aim of the present in vitro study was to evaluate the effect of charcoal containing whitening toothpastes on the color stability and surface roughness of coffee-stained Nanohybrid.

Materials and Methodology: A total of 50 disc-shaped specimens measuring 6 × 3 mm were prepared using nanohybrid composite resin and immersed in coffee solution to simulate extrinsic staining. Color stability and surface roughness were measured using a spectrophotometer and profilometer at baseline (T0), after staining (T1), and after brushing (T2). The specimens were divided into five groups (n = 10): distilled water, Colgate Total 12 non-charcoal toothpaste, Dabur Herb'l Activated Charcoal toothpaste, Curaprox Black Is White toothpaste, and Colgate Charcoal toothpaste. Brushing was performed using an electric toothbrush for 30 seconds, three times daily, for one week. Statistical analysis done by using one-way ANOVA with $p < 0.05$.

Results: Charcoal-containing whitening toothpastes showed significantly greater color alteration and surface roughness than non-charcoal toothpaste. Dabur Herb'l Activated Charcoal toothpaste exhibited the highest changes, while Curaprox showed lesser effects.

Conclusion: Charcoal-containing whitening toothpastes adversely affected the surface texture and color stability of nanohybrid composite resin.

Keywords: Activated charcoal, whitening toothpaste, nanohybrid composite resin, color stability, surface roughness

Introduction

Composite resin restorations are extensively used in modern restorative dentistry because of their excellent esthetics, conservative tooth preparation, and adhesive properties.[1]

The clinical longevity of composite restorations is strongly influenced by their ability to maintain surface smoothness and color stability over time.[2]Surface degradation and increased roughness may promote plaque accumulation, staining, and wear, thereby

compromising the esthetic and functional performance of restorations.[3]

Discoloration of resin composites may occur due to intrinsic and extrinsic factors.[4] Extrinsic staining caused by dietary chromogens such as coffee, tea, and tobacco is considered one of the major causes of color alteration in composite restorations.[5]
Among these beverages, coffee has been reported to produce significant discoloration because of its high yellow pigment content and its affinity for the organic resin matrix.[6]
Furthermore, water sorption and adsorption of staining agents into the resin matrix may accelerate color instability of composite materials.[7]

In recent years, whitening toothpastes have become increasingly popular among individuals seeking improved dental esthetics. [8] Activated charcoal-containing dentifrices are widely promoted for their stain-removing and whitening properties. [9] These dentifrices contain abrasive charcoal particles that may contribute to surface alterations of restorative materials.[10]

Previous studies have reported that charcoal-based whitening toothpastes can significantly increase the surface roughness and discoloration of composite resins when compared with conventional dentifrices[11].Increased surface roughness may further predispose restorations to plaque retention and additional staining[12].

Recent systematic reviews have highlighted the limited and conflicting evidence regarding the long-term effects of charcoal-containing whitening toothpastes on restorative materials[13]. Although several studies have evaluated the influence of charcoal dentifrices on enamel and restorative materials, limited literature is available regarding their effect on coffee-stained nanohybrid composite resin.[14]
Therefore, the present in vitro study was undertaken to evaluate the effect of charcoal-containing whitening toothpastes on the color stability and surface roughness of coffee-stained nanohybrid composite resin.

Materials And Methodology

The present in vitro study was conducted to evaluate the effect of charcoal-containing whitening toothpastes on the color stability and surface roughness of coffee-stained nanohybrid composite resin.

Specimen Preparation

A total of 50 disc-shaped specimens were prepared using nanohybrid composite resin. Each specimen measured 6 mm in diameter and 3 mm in thickness. The composite material was packed into a customized cylindrical stainless -steel mold placed over a glass slab covered with a Mylar strip. Another Mylar strip and glass slide were placed over the mold to obtain a smooth surface and to remove excess material. The specimens were light cured according to the manufacturer's instructions using a LED curing unit. After curing, all specimens were finished and polished using polishing discs under standardized conditions.

Staining Procedure

The prepared specimens were immersed in coffee solution to simulate extrinsic staining. The coffee solution was prepared by dissolving coffee powder in distilled water under standardized concentration. All specimens were stored in the staining solution for a standardized duration of 24 hours at room temperature. Following staining, the specimens were rinsed with distilled water and dried gently using absorbent paper.

Baseline Measurements

Baseline color stability and surface roughness values were recorded before staining (T0) and after staining (T1). Color measurements were obtained using a spectrophotometer based on the CIE L*ab** color system. Surface roughness measurements were assessed using a profilometer, and the mean roughness value (Ra) was recorded for each specimen.

Grouping Of Specimens

The specimens were randomly divided into five groups (n = 10):

1. Group 1: Distilled water (negative control)
2. Group 2: Colgate Total 12 non-charcoal toothpaste (positive control)
3. Group 3: Dabur Herb'l Activated Charcoal toothpaste
4. Group 4: Curaprox Black Is White toothpaste
5. Group 5: Colgate Charcoal toothpaste

Brushing Procedure

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Toothbrushing was performed using an electric toothbrush under standardized conditions. A toothpaste slurry was prepared by mixing toothpaste with distilled water in a standardized ratio of 1:2. Each specimen was brushed for 30 seconds, three times daily, for a period of one week. Between brushing cycles, the specimens were stored in distilled water at room temperature.

Final Measurements

After completion of the brushing regimen, final color stability and surface roughness measurements were recorded (T2) using the same spectrophotometer and profilometer. The color difference (ΔE) values were calculated using the CIE L*ab** formula.

Statistical Analysis

The data were compiled and analyzed using the Statistical Package for the Social Sciences (SPSS), version 20.0 (IBM Corp., Armonk, NY, USA). All quantitative data were expressed as mean ± standard deviation. Paired t-test was used to compare surface roughness and colour values of the composite specimens before and after coffee immersion (n = 50). After coffee staining, the specimens were randomly allocated into five groups (n = 10 per group) and treated with different solutions. Intergroup comparisons of surface roughness and colour change after brushing were carried out using one-way analysis of variance (ANOVA). Tukey's (HSD) post-hoc test was applied for multiple pairwise comparisons. A p-value of less than 0.05 was considered statistically significant.

Discussion

The present in vitro study evaluated the effect of charcoal-containing whitening toothpastes on the color stability and surface roughness of coffee-stained nanohybrid composite resin. The results demonstrated that charcoal-based whitening toothpastes produced significantly greater alterations in both color stability and surface roughness when compared with conventional non-charcoal toothpaste.

Composite resin restorations are widely used because of their excellent esthetic properties; however, discoloration and surface degradation remain major clinical concerns affecting their long-term success.[1] Color stability of resin composites is influenced by several factors, including the composition of the resin matrix, filler particle characteristics, water sorption, dietary staining agents, and surfaceroughness.[2] In the present study, coffee was used as the staining solution because it is considered one of the most chromogenic beverages and has a strong affinity for the organic resin matrix.[3] The staining ability of coffee has been attributed to adsorption and absorption of yellow pigments into the resin matrix, resulting in clinically perceptible discoloration.[4]

The present study demonstrated that charcoal-containing whitening toothpastes caused

greater color alteration compared with non-charcoal toothpaste. This finding may be attributed to the abrasive charcoal particles present in these dentifrices, which can increase surface irregularities and facilitate stain retention.[5] Among the charcoal groups, Dabur Herbal Activated Charcoal toothpaste showed the highest color change, followed by Colgate Charcoal toothpaste, whereas Curaprox Black Is White toothpaste exhibited comparatively lesser discoloration. Differences in formulation, abrasive particle size, and relative dentin abrasivity (RDA) values among the tested dentifrices may explain these variations.[6]

Surface roughness analysis in the present study revealed significantly higher roughness values in specimens brushed with charcoal-containing whitening toothpastes. Increased surface roughness may compromise gloss, esthetics, and plaque resistance of composite restorations.[7] The abrasive nature of activated charcoal particles has been reported to produce surface wear and microstructural defects in restorative materials.[8] Previous studies have similarly reported increased roughness and discoloration of composite resins after brushing with charcoal-containing dentifrices.[9,10]

The non-charcoal toothpaste demonstrated comparatively minimal changes in both color stability and surface roughness. This may be related to the lower abrasivity and more controlled polishing effect of conventional dentifrices when compared with charcoal-based products.[11]

The findings of the present study are in agreement with the studies conducted by Forouzanfar et al.[12] and Gömleksiz and Okumuş[13] who reported that charcoal-containing whitening toothpastes adversely affected

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the color stability and surface properties of composite restorations. Similarly, Torso et al. observed that charcoal-based dentifrices increased surface wear and discoloration of resin composite materials.[14]

Despite the valuable findings obtained in this study, certain limitations should be considered. The study was conducted under in vitro conditions that may not completely simulate the oral environment. Factors such as salivary flow, pH fluctuations, dietary variations, and intraoral temperature changes were not reproduced. In addition, only one type of nanohybrid composite resin and a limited brushing duration were evaluated. Further long-term in vivo studies are recommended to better understand the clinical effects of charcoal-containing whitening toothpastes on restorative materials.

Limitations Of The Study

The present study was conducted under in vitro conditions, which may not completely simulate the complex oral environment. Factors such as salivary flow, thermal fluctuations, masticatory forces, pH variations, and oral biofilm were not reproduced. In addition, only one type of nanohybrid composite resin and a limited brushing duration were evaluated. Therefore, the clinical performance of charcoal-containing whitening toothpastes may vary under intraoral conditions

Conclusion

Within the limitations of the present in vitro study, it can be concluded that charcoal-containing whitening toothpastes adversely affected the color stability and surface roughness of coffee-stained nanohybrid composite resin.

Among the tested dentifrices, Dabur Herb'l Activated Charcoal toothpaste exhibited the highest color alteration and surface roughness values, followed by Colgate Charcoal toothpaste, whereas Curaprox Black Is White toothpaste demonstrated comparatively lesser effects.

The conventional non-charcoal toothpaste showed minimal changes in both color stability and surface roughness when compared with the charcoal-containing whitening toothpastes.

The increased abrasiveness of activated charcoal particles may contribute to surface degradation and enhanced discoloration of composite restorations. Therefore, prolonged use of charcoal-containing whitening toothpastes may compromise the esthetic longevity of nanohybrid composite restorations.

Further long-term in vivo studies are recommended to evaluate the clinical effects of charcoal-containing whitening dentifrices on restorative materials under oral conditions.

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Table 1: Comparison of surface roughness and colour change before and after coffee immersion (Paired t-test)

Parameter	Before (Mean ± SD)	After (Mean ± SD)	t value	df	p value

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Surface roughness (RZ)	2.64 ± 0.03	6.01 ± 0.02	-1038.78	49	<0.001*
Colour change (ΔE)	3.12 ± 0.16	7.80 ± 0.10	-249.98	49	<0.001*

Paired t test;*Statistically significant

The paired t-test demonstrated a statistically significant increase in both surface roughness and colour change of the nano-hybrid composite specimens following coffee immersion. The mean surface roughness (RZ) increased from 2.64 ± 0.03 before immersion to 6.01 ± 0.02 after immersion ($t = -1038.78$, $p < 0.001$). Similarly, the mean colour change (ΔE) showed a significant rise from 3.12 ± 0.16 to 7.80 ± 0.10 after coffee immersion ($t = -249.98$, $p < 0.001$), reflecting pronounced staining of the composite material. These findings confirm that coffee immersion significantly affects both the surface roughness and colour stability of the composite resin.(Table 1)(Figure 1)

Table 2: Comparison of surface roughness (RZ) and colour change (ΔE) among different groups after brushing (One-way ANOVA)

		Surface roughness (RZ)	Colour change (ΔE)
Group	N	Mean ± SD	Mean ± SD
Distilled water	10	4.79 ± 0.17	6.40 ± 0.03
Positive control	10	3.73 ± 0.15	7.22 ± 0.03
Herbal charcoal	10	3.49 ± 0.20	8.82 ± 0.03
Colgate charcoal	10	3.54 ± 0.20	8.21 ± 0.04
Curaprox charcoal	10	3.73 ± 0.15	5.80 ± 0.01
F		92.497	16874.04
P value		< 0.001*	< 0.001*

One way ANOVA; *Statistically significant

One-way analysis of variance revealed a statistically significant difference in both surface roughness and colour change among the five groups after brushing ($p < 0.001$). For surface roughness, the distilled water group exhibited the highest mean RZ value (4.79 ± 0.17), indicating greater surface deterioration, whereas the herbal charcoal (3.49 ± 0.20) and Colgate charcoal (3.54 ± 0.20) groups showed comparatively lower roughness values. Regarding colour change, the herbal charcoal group demonstrated the maximum mean ΔE value (8.82 ± 0.03), followed by the Colgate charcoal group (8.21 ± 0.04), while the Curaprox charcoal group showed the least colour change (5.80 ± 0.01). (Table 2)(Figure 2)

Table 3: Tukey post-hoc comparison of surface roughness (RZ) and colour change (ΔE) after brushing

	RZ		ΔE	
Group comparison	Mean difference	p value	Mean difference	p value
Distilled water vs Positive control	1.06	<0.001*	−0.82	<0.001*

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Distilled water vs Herbal charcoal	1.30	<0.001*	−2.42	<0.001*
Distilled water vs Colgate charcoal	1.25	<0.001*	−1.82	<0.001*
Distilled water vs Curaprox charcoal	1.06	<0.001*	0.60	<0.001*
Positive control vs Herbal charcoal	0.24	0.029*	−1.60	<0.001*
Positive control vs Colgate charcoal	0.19	0.128	−0.99	<0.001*
Positive control vs Curaprox charcoal	0.00	1.000	1.42	<0.001*
Herbal charcoal vs Colgate charcoal	0.05	0.968	0.61	<0.001*
Herbal charcoal vs Curaprox charcoal	0.24	0.029*	3.02	<0.001*
Colgate charcoal vs Curaprox charcoal	0.19	0.128	2.41	<0.001*

*Statistically significant

Tukey's post-hoc analysis revealed statistically significant pairwise differences in surface roughness and colour change between several groups following brushing. For surface roughness (RZ), the distilled water group showed significantly higher roughness compared with all other groups ($p < 0.001$). The herbal charcoal group also demonstrated significantly lower surface roughness compared to the positive control and Curaprox charcoal groups ($p = 0.029$), whereas no significant differences were observed between the positive control and Colgate charcoal groups, or between Colgate charcoal and Curaprox charcoal groups ($p > 0.05$).

With respect to colour change (ΔE), significant differences were observed between all group comparisons ($p < 0.001$). The herbal charcoal group exhibited significantly greater colour change when compared with all other groups, while the Curaprox charcoal group demonstrated significantly lower colour change compared to the remaining groups.(Table 3)

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Figure 1: Comparison of surface roughness and colour change before and after coffee immersion

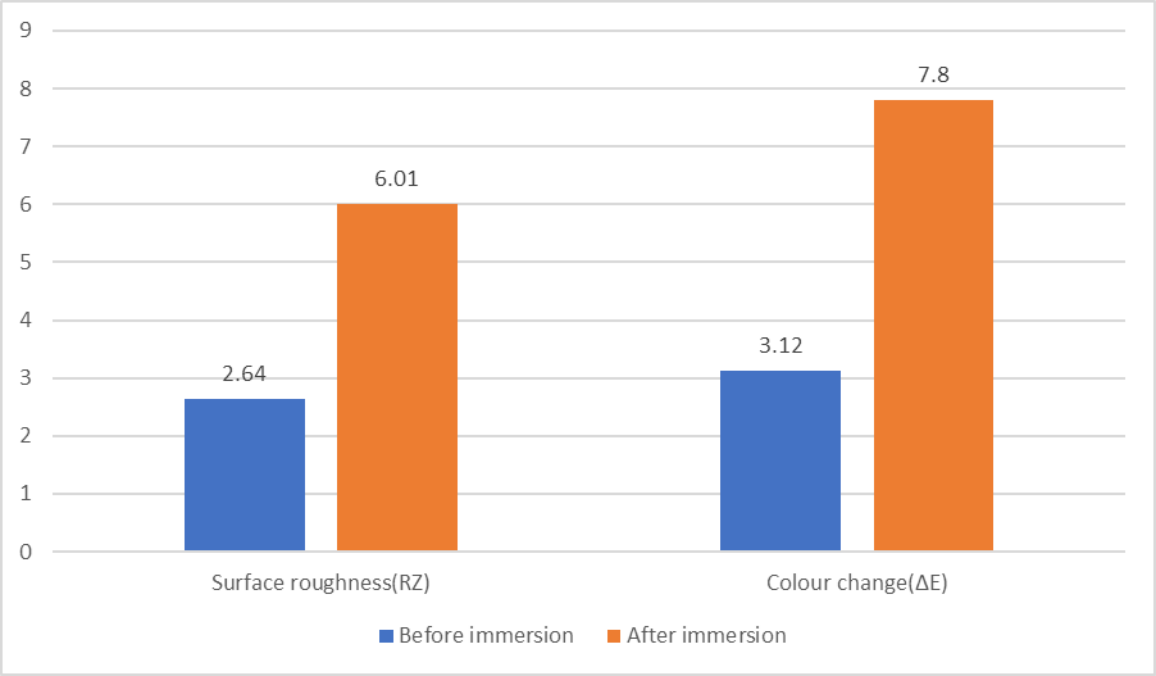
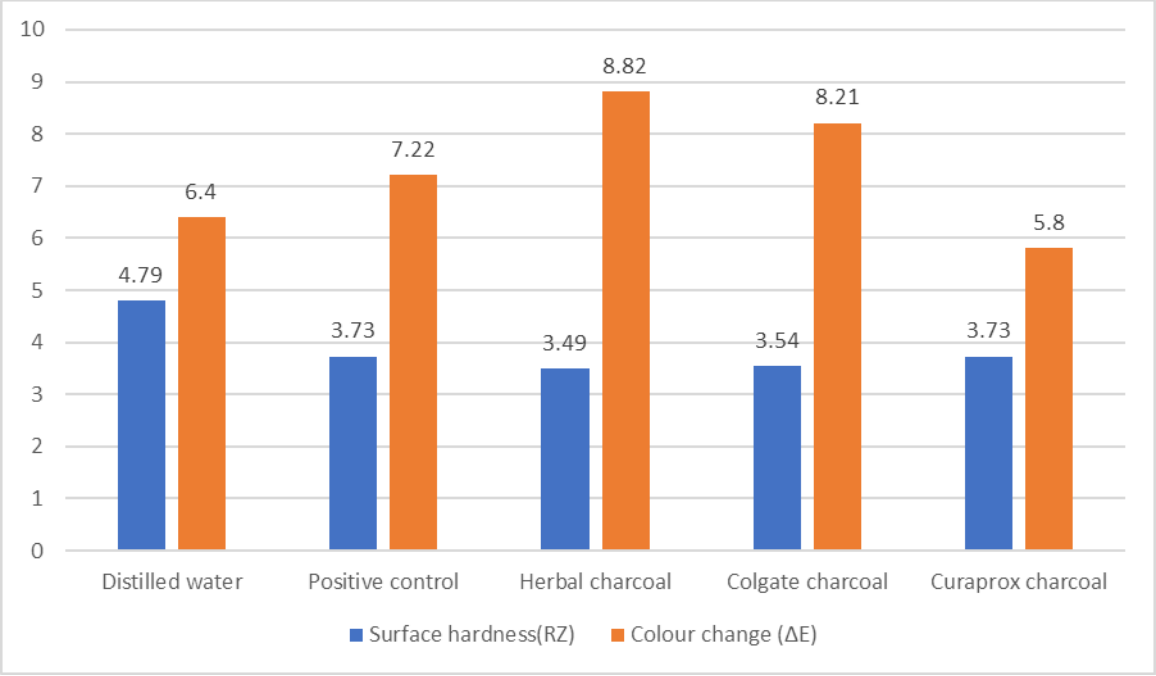


Figure 2: Comparison of surface roughness (RZ) and colour change (ΔE) among different groups after brushing



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