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ORIGINAL ARTICLE

Efficiency of activated charcoal powder in stain removal and effect on surface roughness compared to whitening toothpaste in resin composite: In vitro study

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KEYWORDS

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Abstract *Objectives:* To evaluate the efficacy of activated charcoal powder on extrinsic stain removal and its effect on surface roughness in stained resin composite in comparison with whitening toothpaste.

Materials and methods: Sixty-six disk-shaped composite specimens were fabricated using a custom-made ring mold. The specimens were stained using a coffee solution and stored in distilled water at 37 °C. The specimens were divided randomly into two groups, Group 1: Thirty-Three disks were subjected to brushing using whitening toothpaste (Control), and Group 2: Thirty-Three disks were subjected to brushing using charcoal powder. Specimens were evaluated for surface color and surface roughness at baseline after staining protocol and after the brushing process.

Results: Changes in color and surface roughness were highly significant ($p < 0.0001$) after brushing with activated charcoal powder and whitening toothpaste. However, no significant differences were found in color ($p = 0.90$) and surface roughness ($p = 0.33$) between the two bleaching techniques.

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Conclusion: The changes in the color and surface roughness of resin composite was significant after brushing with activated charcoal powder and whitening toothpaste. However, there were no significant differences between the two techniques.

1. Introduction

Esthetic dentistry became a worldwide demand. One approach to achieve high esthetic results is bleaching which is considered an effective and noninvasive method (Baldea et al. 2017, Moraes et al. 2006). Although teeth bleaching is generally safe some adverse effects may develop following whitening procedures. The most common side effect is teeth sensitivity which develops in 15–78% patients after treatments. (Tredwin et al. 2006) Increased enamel surface roughness is another effect of bleaching that could increase the susceptibility for extrinsic discoloration after bleaching. Other adverse effects are transient gingival irritation, increased glass ionomer solubility, and decreased bonding strength of bonded restorations to the tooth structure (Ren et al. 2009, Tredwin et al. 2006).

With all the advances regarding the properties of esthetic restorative materials, color stability is still a problem. Composite resins are susceptible to discoloration after use in the oral environment. Material composition and curing technique could affect the color stability of composite resins. Filler type may also be attributed to the staining susceptibility of composite resin. Nanohybrid composite absorbs staining substances more easily than microhybrid composite (Poggio et al. 2012). Resin composite undergoes multiple modifications to introduce more desirable criteria such as color stability and better surface characteristics. One of the methods to accomplish such criteria is to reduce the fillers' size within the resin composite. Surface roughness can directly affect the esthetic appearance of a restoration. Unfinished and rough composite surfaces are more susceptible to staining. Teeth brushing can increase the roughness and affect the surface texture of the resin composite (da Costa et al. 2010). The abrasiveness of the dentifrices may increase resin composite surface roughness leading to compromised esthetics of the restoration. Abrasive components in dentifrices and toothbrush bristles may damage the tooth surface and the outer surface of the composite (Roopa, 2016). Some studies show that bleaching could partially remove discoloration in resin composite (Türkün and Türkün, 2004, Villalta et al. 2006). Therefore, introducing a new bleaching agent based on natural products with comparable esthetic results and minimal adverse effects would be beneficial either to bleach the teeth or remove resin composite extrinsic stains (Baldea et al. 2017).

Recent increased interest in using charcoal containing compound for teeth whitening has taken place due to its ability to absorb pigments, chromophores, and stains (Vaz et al. 2019). Charcoal containing products become popular in the current time, advertisement in the social media may improve its spread in multiple regions (Greenwall et al. 2019). Using charcoal-containing compounds has been an ancient practiced in different parts of the world for cleaning or cosmetic purposes (Brooks et al. 2017). Teeth powder was one of the countryside practicing methods in performing oral hygiene and they consider it as an herbal product. These teeth powders' content usually is unknown, but their abrasiveness is five times more in comparison to toothpaste (Singh et al. 2016). The abrasive potential of charcoal containing products depends on the size and distribution of particles and the manufacturing process. Some forms of charcoal based dentifrices have been found to be highly abrasive, which will be more effective in extrinsic stain removal and surface deposits. However, the high abrasive potential may cause loss of tooth surface structure (Greenwall et al. 2019). Most users of charcoal-based dentifrices are based on the product's claims of teeth whitening. In achieving this goal, users tend to brush strenuously for a longer time which may lead to more destruction, especially in restorations with abrasion resistance. Teeth brushing using charcoal powder or charcoal-based dentifrices may lead the charcoal particles to remain in the gingival sulcus, build up in deep pits and fissures, and marginal or surface defects of restorations resulting in a compromised esthetic of teeth colored restorations (Greenwall et al. 2019). More studies of charcoal containing product to assess their performance and safety are needed. These products must rely on research based evidence and not only on manufacturer instructions (Brooks et al. 2017).

This study aims to evaluate the efficacy of activated charcoal powder on extrinsic stain removal and its effect on the surface roughness of the stained resin composite compared to hydrogen peroxide containing toothpaste. The null hypothesis is that activated charcoal powder has no effect on stain removal, and on the surface roughness of stained resin composite and that there are no differences in effect between activated charcoal powder and hydrogen peroxide containing toothpaste.

2. Material and methods

2.1. Samples preparation

Sixty-six disk shaped composite resin specimens with an inner diameter of 10mm and 2mm thickness were fabricated. Uncured composite (IPS empress direct composite, A2 enamel shade) was packed into a custom made ring mold sandwiched between two clear strips and two glass plates. The specimens were light cured following manufacturer's instructions. The specimens were polymerized by BluephaseÒ meter (LED curing light designed with "poly wave") with an intensity of 1000 mW/cm2 for 10 s (Fig. 1). After light curing, specimens were removed carefully from the mold then immersed in distilled water and stored inside the JSGI- 150 T incubator at 37 °C to stimulate mouth temperature for 24 h for final polymerization. Specimens were placed within ring mold and putty for easily handling during finishing and polishing procedures. Finishing and polishing were performed using (Automata Grinding and Polishing Unit) with 600 grit for 20 s for each

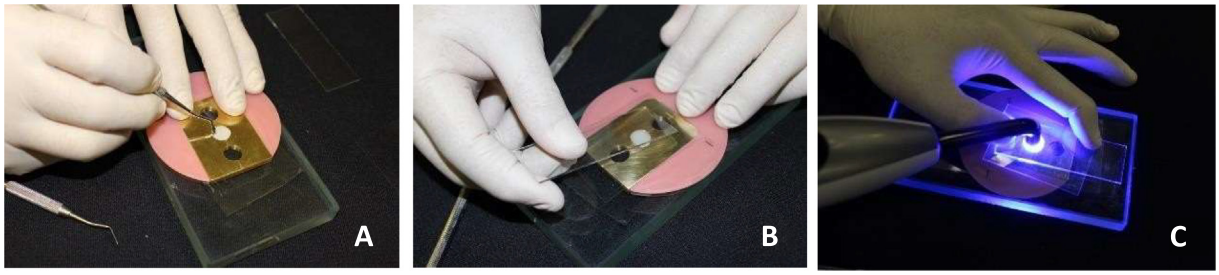

Fig. 1 (A) Packing composite into a custom made ring mold. (B) Mylar strips and glass plate application. (C) Light curing.

specimen to stimulate finishing and polishing during clinical procedure.

2.2. Staining process

After finishing and polishing, the specimens were immersed in a black coffee solution. The coffee solution was prepared with 15 g of (Nescafé® classic) mixed in 500 ml water at boiling temperature. After waiting for 10 min to achieve drinking temperature, the specimens were immersed into the coffee for 20 min, every 24 h for 14 days to simulate twice a day coffee consumption for 1 year. The specimens were then washed and stored in water in the incubator at 37 °C. The specimens were divided randomly into two groups. Group1: Thirty-three disks of the stained composite were subjected to brushing, in which whitening toothpaste was used. Group2: Thirty-three disks of the stained composite were subjected to brushing, in which activated charcoal powder was used. Specimens were evaluated for color stability and surface roughness at two intervals: at baseline; after staining protocol and after brushing with activated charcoal powder (Active Carbon, Yumaki®) or whitening toothpaste containing hydrogen peroxide (Colgate® Optic White® Expert).

2.3. Brushing process

Brushing was performed using a brushing machine (Zahnbürstsimulation Zm-3, SD Mechatronik). Specimens were placed within a ring mold and putty and stabilized in the machine for easier handling during the brushing procedure (Fig. 2). The brushing force was 1.6 N with a linear movement pattern in a horizontal direction with a travel length of 15 mm and a speed of 35 mm/s. Specimens were individually subjected to 1120 mechanical brushing cycles in total which is equal to four weeks of brushing in a regular oral hygiene practice (Baldea et al. 2017). In group 1, each time the toothbrush head was loaded with toothpaste slurry of 0.25 mg. For group 2, the toothbrush head was loaded with a 0.25 mg mix of activated charcoal powder and water in a ratio of 3:1. After brushing, the specimens were washed, dried, and submitted to a new color and surface roughness measurement.

2.4. Color testing

CIE (Commission Internationale de l'Eclairage) L*a*b* values were obtained with a LabScan XE spectrophotometer (CM 2500d, Minolta, Osaka, Japan) and D65 light which allows the determination of color in the three-dimensional space. A jig was designed to place the composite disk over the aperture in the same place each time. All measurements were repeated three times by changing the position of the specimen 90° quarter and the average of the three readings was calculated. The total color difference between baseline measurements and after the brushing process was calculated using the application of the Hunters equation:

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

The L* represent a lightness difference, a* represents a redness or greenness difference, and b* represents the blueness yellowness difference between a sample and standard colors.

2.5. Surface roughness testing

Characterization and imaging were performed using a Contour GT-K 3D Optical Microscope (Bruker®), 3D non-contact surface metrology with interferometry. A 5x Michelson magnification lens was used with a field of view of 1.5 × 1

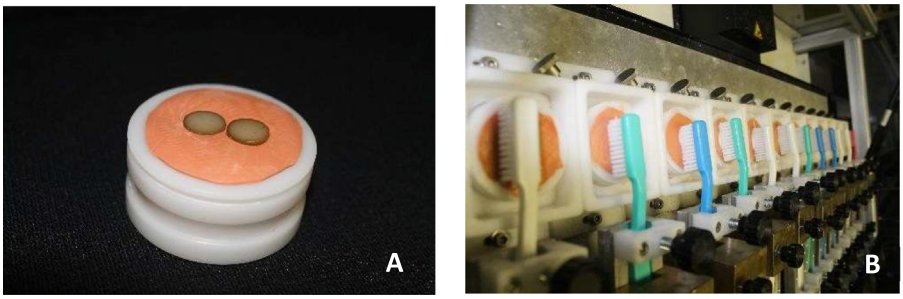

Fig. 2 (A) Stabilizing composite disk within a ring mold and putty. (B) Stabilizing the ring mold and toothbrushes into the brushing machine.

.5 mm, the scan speed of 1x, and threshold of 3. Samples were placed on the stage and manually adjusted to give an image on the monitor screen. The microscope uses a Vision 64 (Bruker®) software that controls the settings and data analyses. The measurement was performed using vertical scanning interferometry, which uses a broadband normally white light source to measure objects with rough surfaces, as well as adjacent height differences greater than 135 nm. Each sample was scanned at five intervals and averaged accordingly to determine the roughness (Ra) value.

2.6. Statistical analysis

The normality of the data was verified by Shapiro-Wilk test. Descriptive statistics for each group were reported as means and standard deviations. Paired *t*-test was used to compare color and surface roughness before and after the use of each whitening technique. Two sample *T*-test was used to compare the effect of the two bleaching techniques on color and surface roughness. All statistical testing was done at a level of $\alpha = 0.05$ and using SAS software (SAS Institute Inc., Cary, NC) version 9.4.

3. Results

Results indicate that after both bleaching techniques, the surface color of stained composite resin showed a statistically significant increase in ΔE by an average of 2.63 after brushing with whitening toothpaste ($p < 0.0001$) and an average of 2.64 after brushing with activated charcoal powder ($p < 0.0001$). The change in color coordinates L, a, and b was significant after brushing with whitening toothpaste ($p < 0.0001$) by an average of 1.32, −0.28, and −2.18 respectively ($p < 0.0001$). Changes after brushing with activated charcoal powder was significant ($p < 0.0001$) with an average of −1.6, −0.02, and −1.95 in L, a, and b respectively. Surface roughness was significantly higher after the use of whitening toothpaste by an average of 1.96 ($p < 0.0001$). Similarly, after the use of activated charcoal powder, higher surface roughness was observed by an average of 2.25 ($p < 0.0001$). (Table 1, 2)

When comparing between the two bleaching techniques, the results did not show a statistically significant difference in the change of surface color (ΔE) (P-value = 0.90). However, the change in color lightness and in redness/greenness were statistically significant between the two groups ($p < 0.0001$).

The change in surface roughness was observed in both techniques, with a slightly higher roughness in samples brushed with activated charcoal powder compared to samples brushed with whitening toothpaste. However, this difference was not statistically significant (P-value = 0.33). (Table3)

Table 1 Mean and standard deviation of surface characteristics before and after the use of whitening toothpaste.

Surface characteristics		Difference (Before-After)	P-value*
Color	**ΔE**	2.63 ± 0.48	< 0.0001
	ΔL	1.32 ± 0.62	< 0.0001
	Δa	−0.28 ± 0.17	< 0.0001
	Δb	−2.18 ± 0.42	< 0.0001
Roughness		1.96 ± 1.04	< 0.0001

*Paired *T*-test.

Table 2 Mean and standard deviation of surface characteristics before and after the use of activated charcoal.

Surface characteristics		Difference (Before-After)	P-value*
Color	**ΔE**	−2.64 ± 0.61	< 0.0001
	ΔL	−1.60 ± 0.73	< 0.0001
	Δa	−0.02 ± 0.22	< 0.0001
	Δb	−1.95 ± 0.65	< 0.0001
Roughness		2.25 ± 1.39	< 0.0001

*Paired *T*-test.

4. Discussion

This study aimed to evaluate the effectiveness of activated charcoal powder in stain removal and its effect on surface roughness in stained resin composite compared to whiting toothpaste containing hydrogen peroxide. Also, to assess the effect of activated charcoal powder and whitening toothpaste in stain removal and effect on surface roughness within each group independently. The null hypothesis was rejected because the activated charcoal powder was found to be effective in stain removal, and it has an effect on surface roughness. However, there were no statistically significant differences observed between the two bleaching techniques. Activated charcoal powder relies on mechanical or abrasive activity and the capability of absorbing pigments, chromophores, and stains to remove stains from resin composite (Vaz et al. 2019). The activation process removes impurities and creates fine small particles. Increasing internal pours producing a high surface area which results in effective and progressive cleaning of the dentition. Although activated charcoal's ability to whiten has not been scientifically proven, most activated charcoal toothpaste manufacturer advertise their products as teeth whitening pastes (Brooks et al. 2017). Studies on the effectiveness of charcoal powder on extrinsic stain removal and surface roughness of resin composite are scarce. Teeth color is considered a significant interest over many years. A previous study showed that 25–55% are unsatisfied with their teeth color. A coffee solution was used to stain resin composite disks because evidence proves that coffee is one of the most consumed beverages that enhance composite discoloration (Reinhardt et al. 2019). Many studies on the effect of coffee on resin composite reported that coffee pigments would cause discoloration in tested materials (Scotti et al. 1997, Stober et al., 2001, Um and Ruyter, 1991). In the present study, two parameters including color stability and surface roughness were evaluated. The readings of the two parameters were taken at two intervals, one at baseline after the staining process and the other after four weeks of mechanical brushing. Color and surface roughness were evaluated after four weeks to stimulate routine oral hygiene procedures (Wiegand et al. 2009). In 4 weeks the number of cycles was 1120. The mechanical brushing method was used to standardize the brushing forces and speed on the specimens.

Table 3 Comparison of mean difference and standard deviation between bleaching techniques on surface characteristics.

Surface characteristics		Activated Charcoal N = 33	Whitening Toothpaste N = 33	P-value*
Color	**ΔE**	2.64 ± 0.61	2.63 ± 0.48	0.90
	ΔL	−1.60 ± 0.73	1.32 ± 0.62	< 0.0001
	Δa	−0.02 ± 0.22	−0.28 ± 0.17	< 0.0001
	Δb	−1.95 ± 0.65	−2.18 ± 0.42	0.10
Roughness		2.25 ± 1.39	1.96 ± 1.04	0.33

*Two-sample *T*-test.

4.1. Surface color

The results indicate that after both bleaching techniques, the surface color of stained resin composite showed a statistically significant increase in ΔE after brushing with whitening toothpaste and activated charcoal powder when comparing to the baseline measurements. Although the ΔE values of the present study 2.64 ± 0.61 for activated charcoal powder and 2.63 ± 0.48 for whitening toothpaste are visually detectible by the human eye, values less than 3.3 ΔE units are considered clinically insignificant regarding color differences (Canay and Çehreli, 2003, Çelik et al. 2009, Hubbezoglu et al. 2008, Kurtulmus-Yilmaz et al., 2013). Studies on the effect of whitening dentifrice on resin composite show a highly significant color change after two weeks of use (Roopa, 2016). When comparing the surface color between the two bleaching techniques, no significant difference was observed. This was inconsistent with a previous study (Vaz et al. 2019) which founds that whitening toothpaste with hydrogen peroxide performs better after regular use compared to activated charcoal containing toothpaste. A reason for this could be due to differences in tested surfaces, instead of composite resin they used dental enamel samples. The color change in composite resin could be due to the removal of superficial stains and exposing a cleaner, more polished surface by the abrasive components of whiting and charcoal toothpaste.

4.2. Surface roughness

The results show that surface roughness was significantly higher after the use of whitening toothpaste and activated charcoal powder in comparison to the baseline measures. Similar results were reported in other studies comparing different types of whitening toothpaste (da Rosa et al. 2016, dos Santos et al. 2019). Another study found that there was a significant increase in surface roughness regardless of the composites' types after brushing with different whitening dentifrices (da Costa et al. 2010, Roopa, 2016) reported that compared to conventional toothpaste samples brushed with whiting toothpaste had a significant change in surface roughness. Increased surface roughness has an influence on restoration aesthetics. Rough surfaces lead to the accumulation of plaque and stains which may lead to discoloration and secondary caries. Regarding the activated charcoal effect, only one study was found evaluating the effect on the enamel surface. They reported that brushing with activated charcoal increased roughness in the enamel surface (Palandi et al. 2020). No studies were found regarding the effect of activated charcoal powder on the surface roughness of resin composite.

4.3. Limitations

The results are obtained based on in vitro study. The presence of saliva and its effect on surface characteristics of restorative materials was not measured. Randomized clinical trials should be performed to evaluate the effectiveness and the safety of activated charcoal powder on dental tissues and aesthetic restorative materials.

5. Conclusion

Within the limitations of the study, it can be concluded that brushing with activated charcoal powder or whitening toothpaste will affect the color and surface roughness of composite resin. However, no significant differences were found between the two bleaching techniques.

CRediT authorship contribution statement

Raneem S. Alofi: Conceptualization, Methodology, Resources, Writing - review & editing, Supervision. **Haya A. Alsuayri:** Conceptualization, Methodology, Investigation, Writing - original draft. **Lojain S. Mohey:** Conceptualization, Methodology, Investigation, Writing - original draft. **Adeem S. Alofi:** Formal analysis, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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