

Original Article

Effect of whitening toothpastes containing activated charcoal, abrasive particles, or hydrogen peroxide on the color of aged microhybrid composite

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ABSTRACT

Background: This study aimed to assess the effect of different whitening toothpastes containing activated charcoal, abrasive particles or hydrogen peroxide on the color of aged microhybrid composite.

Materials and Methods: In this *in vitro*, experimental study, 45 composite discs (2 mm × 7 mm) were fabricated of a microhybrid composite. They underwent accelerated artificial aging for 300 h, corresponding to 1 year of clinical service. The composites were then randomly divided into five groups ($n = 9$). One group served as the control and underwent tooth brushing with distilled water. The remaining four groups underwent tooth brushing with Colgate Total whitening (Gt), Colgate Optic White (Go), Perfect White Black (Gp) and Bencer (Gb) toothpastes in a brushing machine. The International Commission on Illumination values (L_m, a_m, b_m) were determined using a spectrophotometer. Color change (ΔE) calculated based on this formula: $\Delta E_m = ([\Delta L_m]^2 + [\Delta a_m]^2 + [\Delta b_m]^2)^{1/2}$. The differences were defined by ΔE_1 (after aging-baseline), ΔE_2 (after brushing-after aging) and ΔE_3 (after brushing-base line). ΔE_1 were evaluated to ensure that color mismatch had occurred ($\Delta E_1 > 5.5$). Difference in (L, a, b) parameters after aging and after tooth brushing in each group, color parameter changes ($\Delta L_2, \Delta a_2, \Delta b_2, \Delta L_3, \Delta a_3, \Delta b_3$) and ΔE_2 and ΔE_3 were analyzed and compared using Wilcoxon test and independent sample median test at $P = 0.05$ level of significance.

Results: The color parameter changes, ΔE_3 and ΔE_2 were not significantly different among the five groups ($P > 0.05$). In Gp and Gb charcoal a^* , b^* , and L^* after tooth brushing ($P < 0.05$). In Colgate Optic group, the a^* parameter significantly decreased while the L^* parameter significantly increased ($P < 0.05$).

Conclusion: The results showed that there is no significant difference in the color change of Spectrum composite following tooth brushing with different whitening toothpastes for two weeks. It should be noted that ΔE_3 reached to < 3.3 only in charcoal whitening toothpastes.

Key Words: Aging, color, composite resins, toothpastes

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INTRODUCTION

The important factor in facial beauty and satisfaction with dentofacial appearance based on literature review is tooth color. Current researches have revealed that 17% to 53% of people from different population are dissatisfied with their tooth color.^[1,2]

The increasing demand for shiny white teeth, tooth color improvement and an attractive smile has led to advances in tooth bleaching products and composite resins.^[3] Tooth bleaching is a highly popular esthetic dental procedure. However, some concerns exist with regard to the risks and complications of dental bleaching such as tooth hypersensitivity and gingival irritation as well as increased enamel surface roughness, tooth softening, and subsequently increased risk of demineralization, degradation of dental restorations and unacceptable color change or color mismatch of restorations with the adjacent tooth structure.^[4,5]

Over the counter (OTC) bleaching products such as whitening mouthwashes and toothpastes are also available.^[6] OTC bleaching products are affordable and can be used by patients at home without requiring a supervision by dentists. OTC products are available in the form of gel, whitening strips, dental floss, chewing gums, mouthwashes, and toothpastes. However, toothpastes account for over 50% of OTC bleaching products.^[7,8] This tendency to whitening tooth pastes maybe due to their low cost and easy to use application.^[9]

The whitening tooth paste provide the same anti-caries and anti-gingivitis therapeutic benefits of conventional tooth pastes with additional whitening active components such as abrasives, adsorbent particles, peroxides, enzymes, or optical effect agents.^[10]

The mechanism of action of whitening toothpastes is mainly based on the presence of high amounts of abrasives.^[7,11] Continues usage and the presence of high quantity of abrasive particles in these abrasive toothpastes can improve enamel brightness and reflectance but this may cause excess wear and removal of tooth structure.^[9,10] These features of abrasive whitening toothpaste have led to adding other materials (peroxide, activated charcoal) in whitening toothpastes that allow whitening without the risk of tooth damage.

The efficacy of peroxide in the composition of toothpastes is a matter of discussion due to its low concentration, the natural instability of it in an

aqueous formula, the additional dilution by salivary flow and short duration of contact with the tooth structure. However, previous studies reported that a toothpaste containing 1% hydrogen peroxide significantly decreased the yellowness and increased the brightness of teeth compared with a peroxide-free conventional toothpaste containing silica.^[12-14]

Recently, activated charcoal has gained the spotlight because of its claimed advantages. The whitening effect of this compound is due to its high potential to absorb stains, chromophores and stain spots. This is because the activated charcoal is highly porous and provides a large surface area (>1000 m²/g) for absorption of stains. Although this effect has not been scientifically proven, 96% of commercial products containing activated charcoal claim that they can effectively bleach the teeth.^[14,15]

Composite resins are increasingly used for dental restorations due to their favorable color and minimal invasiveness. Color and surface roughness are important factors determining the durability of composite resin restorations.^[16] Over 80% of patients complain of color mismatch of their composite restorations and adjacent teeth.^[17] Considering the patient's tendency to have whiter teeth and overcome the color mismatch of composite restoration with low cost and easy to use treatment, it seems imperative to evaluate the effect of whitening tooth pastes on the aesthetic quality of composite resin such as color. On the other hand, the composition and physical properties of resin composite compare to enamel are different, so the behavior of these materials are likely affected by brushing with whitening toothpastes.

A few studies have investigated the effect of whitening tooth paste on the color of resin composites.^[2,15,18] These studies evaluated the color immediately after polymerization of composite restoration.

It should be considered that the color alteration and superficial deterioration of a restorative material may be caused by physical/chemical factors such as temperature, pH, humidity, ultraviolet irradiation, absorption, and adsorption of pigments and mechanical factors.^[19] Different methods have been introduced to reconstruct the proposed factors. Accelerated artificial aging (AAA) is a precise method for assessment of physical, chemical, and optical changes of nonmetal restorative materials such as composite resins due to aging.^[20] AAA usually use extensive intervals of exposure to ultraviolet radiation, moisture, and

changes in temperature.^[21] This condition can change reaction of composites in exposure to whitening toothpastes.

To the best of author's information, there is a gap information the influence of whitening tooth paste on the color of aged composites. Thus, this study aimed to assess effect of different whitening toothpastes on the color of aged micro hybrid composite.

MATERIALS AND METHODS

This experimental study was performed on five groups including four groups of whitening tooth pastes and one control group (GC). The sample size for this study was calculated to compare the color change in five groups. If the ratio of mean difference between groups to standard deviation is two, with the test power of 90% and type 1 error rate of 5%, in each group of study nine samples would be required.^[22] Ethical approval code was (IR.TUMS.DENTISTRY.REC.1397.166) in Tehran university of medical sciences. Table 1 presents the materials used in this study and their composition.

Fabrication of samples

A stainless steel mold (2 mm × 7 mm) was used for this purpose. The A2 shade of Spectrum TPH 3 microhybrid composite was applied in the mold placed on a glass slab and a transparent Mylar strip. After applying the composite, another glass slab and Mylar strip were placed over it and it was compressed such that the excess composite leaked out. The sample was then light-cured using a light-curing unit (Guilin Woodpecker Medical Instrument Co.), guilin, China

with 1000 mW/cm² light intensity for 20 s from both sides. The samples were polished with 1000 and 1200-grit abrasive papers with 10 strokes for each side. The testing surface was marked.

Measuring the color parameters before aging

The color parameters of the samples were measured based on the International Commission on Illumination L*a*b* color space using a spectrophotometer (Easysshade, VITA Zahnfabrik, BadSackingen, Germany). The spectrophotometer was used after calibration according to the manufacturer's instructions. The samples were placed against a white background and the three parameters of L*, a* and b* were measured. For the purpose of standardization, a jig with a suitable size for the discs was fabricated. The discs were mounted on the jig and their color parameters were measured three times at the center against a white background, then the mean was calculated.

Aging

The samples underwent AAA in a Xenotest Alpha LM (Heraeus Kulzer, Hanau, Germany) device for 300 h corresponding to 1 year of composite aging in the oral environment. This device had a filter to simulate daylight (within the range of visible light) by changing the spectral energy distribution of xenon lamp. The samples were held by clasps under similar conditions such that they were under full exposure of light. The device was adjusted at 37°C and 100% humidity according to ISO 7491. The color of composite discs was measured again after 300 h of aging by the spectrophotometer as explained earlier. Color change (ΔE_m) calculated based on this formula: $\Delta E_m = ([\Delta L_m]^2 + [\Delta a_m]^2 + [\Delta b_m]^2)^{1/2}$. The

Table 1: Materials used in this study and their composition

Material	Composition
Colgate Optic White (Colgate-Palmolive Company, New York, NY, USA)	Calcium pyrophosphate, propylene glycol, PEG/PPG 116/66 copolymer, PEG-12, glycerin, PVP, flavor, sodium lauryl sulfate, tetrasodium pyrophosphate, silica, hydrogen peroxide, sodium saccharin, phosphoric acid, sucralose, butylated hydroxytoluene, water, sodium monofluorophosphate 0.76% (0.15% w/v fluoride ion)
Colgate Total Whitening (Colgate-Palmolive Company, New York, NY, USA)	Water, hydrated silica, glycerin, sorbitol, PVM/MA copolymer, sodium lauryl sulfate, flavor, cellulose gum, sodium hydroxide, propylene glycol, carrageenan, sodium saccharin, titanium dioxide, sodium fluoride 0.24% (0.15% w/v Fluoride Ion) - triclosan 0.30%
Perfect White Black (Beverly Hills Formula, Ireland)	Water, sorbitol, hydrated silica, glycerin, pentasodium triphosphate, tetrasodium pyrophosphate, sodium lauryl sulfate, aroma, PEG-32, cellulose gum, sodium fluoride, cocamidopropyl betaine, sodium saccharin, charcoal power and Limonene
Bencer charcoal (Sormeh company Tehran, Iran)	Deionized water, dicalcium phosphate dihydrate, glycerin, sorbitol, thickener silica, abrasive silica, sodium lauryl sulfate, mint allowed flavor, sodium carboxymethyl cellulose, polyethylene glycol 1500, sodium mono fluorophosphate, tetra sodium pyro phosphate, methyl paraben, activated carbon, saccharin sodium, propyl paraben menthol
Spectrum TPH 3 Submicron-hybrid composite (DENTSPLY DeTrey, Milford, DE, USA)	Matrix: Bis-GMA-adduct, Bis-EMA, TEGDMA, photo initiators, and stabilizers Filler: 57 vol% (77 wt%) Barium aluminum borosilicate glass (mean particle size <1 mm), barium fluoroaluminoborosilicate (mean particle size <1 mm), and highly dispersed silicon dioxide (particle size 10-20 nm)

differences were determined with ΔE_1 (after aging – base line). Then, it was investigated whether composites showed any color mismatch ($\Delta E_1 > 5.5$) to be included in the study or not.^[23]

Grouping of samples

Composite resins were randomly divided into five groups ($n = 9$). One group served as the Gc and underwent brushing with distilled water while the remaining four groups were subjected to brushing with four toothpastes namely Bencer (Gb), Optic White (Go), Colgate Total Whitening (Gt), and Perfect White Black (Gp).

Brushing of samples

For the purpose of standardization, a device was specifically designed for this purpose. The samples were placed on a glass mold. A mixture of toothpaste and distilled water (50 w/50 w) was prepared in a beaker on a vibrator. The solution was poured in the container of device such that the entire composite surface was immersed in it. Tooth brushing was performed in back-and-forth motion within 5 mm range. The speed of toothbrushing was adjusted at 60 rpm. Each sample was tooth-brushed for one hour corresponding to twice toothbrushing per day, each time for 2 min for a total period of 15 days.^[18] Finally, all samples were rinsed and dried.

The CIE values (L_m, a_m, b_m) were determined using a spectrophotometer again. The color changes (ΔE_m) were calculated based on the formula that mentioned earlier. The differences were defined by ΔE_2 (after brushing-after aging) and ΔE_3 (after brushing-base line).

Statistical analysis

Data were analyzed using SPSS version 24 (IBM Corporation North Castle Drive, MD-NC119 Armonk, NY 10504-1785 US). The Q-Q plot and Shapiro–Wilk test were applied to assess the distribution of data. The results showed that data were not normally distributed. Thus, changes in each of the a^*, b^* and L^* parameters after tooth brushing and after aging in each group and the color parameter changes ($\Delta L_2, \Delta a_2, \Delta b_2, \Delta L_3, \Delta a_3, \Delta b_3$) and ΔE_2 and ΔE_3 were calculated for each toothpaste group and compared using the Wilcoxon test and independent sample median test. $P < 0.05$ was considered statistically significant.

RESULTS

Table 2 presents the a^*, b^* and L^* parameter in the five groups after aging and before tooth brushing.

The b^* parameter significantly decreased after tooth brushing in Gb ($P = 0.008$) and Go ($P = 0.015$) groups, compared with after aging. This reduction was borderline significant for Gp ($P = 0.05$) while it was not significant in Gt ($P = 0.066$). The change in b parameter was not significant in the Gc ($P = 0.72$) according to Wilcoxon test.

The a^* parameter significantly decreased after tooth brushing in Gb ($P = 0.015$) and Gp ($P = 0.038$) groups. This change was not significant in other groups ($P > 0.05$). The L^* parameter increased in all groups after tooth brushing but this increase was only significant in Gb, Go, and Gp ($P = 0.008$).

Table 3 shows color change parameters in specimens. The color parameter changes, ΔE_3 and ΔE_2 were not significantly different among the five groups ($P > 0.05$).

The minimum ΔE_3 was noted in Gb and Gp ($\Delta E < 3.3$), which is the critical threshold for clinically acceptable color change).^[24] The maximum ΔE_2 was noted in Gp (4.1) and the minimum ΔE_2 was noted in Gt (2.02).

DISCUSSION

This study assessed the effect of different whitening toothpastes on the color of aged micro hybrid

Table 2: Median values of color parameters after tooth brushing and after aging

Groups	Time interval					
	Before brushing			After brushing		
	Color parameters					
	L	a	b	L	a	b
Gc	72.1	1.1	17.1	74	0.9	17.1
Gb	74.9	1.7	19.3	76.9	0.7	17.7
Go	74	1.6	19.7	76.8	0.9	17.6
Gt	74.3	1.4	18.7	75.5	1.1	17.9
Gp	74.6	1.2	18.9	75.6	0.6	16.7

Table 3: Median values of $\Delta a, \Delta b, \Delta L, \Delta E$ values of experimental groups between different time intervals

Group	Gc	Gb	Go	Gt	Gp
ΔL_2	1.9	2	2.6	1.24	2
Δb_2	0	-1.57	-2.13	-0.8	-2.23
Δa_2	-0.2	-0.97	-0.67	-0.3	-0.6
ΔE_2	2.82	2.83	3.3	2.02	4.1
ΔL_3	-3.1	-2.7	-4.7	-4.77	-2.5
Δb_3	-4.2	-0.5	-5	-1.8	-4.66
Δa_3	-1.7	--1	-1.6	-1.2	-0.4
ΔE_3	9.97	2.6	8.08	3.84	2.87

composite. The results revealed no significant difference in color change of composite following tooth brushing with whitening toothpastes with different mechanisms of action. Thus, the null hypothesis of the study was confirmed. However, the maximum ΔE_2 was noted in Gp while the minimum ΔE_2 was noted in Gt. The highest and the lowest ΔE_3 was seen in Gc and Gb, respectively. It should be noted that ΔE_3 reached to <3.3 only in Gp and Gb (charcoal whitening toothpastes), which indicates that the color change caused by aging would not be perceivable by the human eye after tooth brushing with charcoal whitening toothpastes after 15 days' application.

Nano crystalline structure of activated charcoal with excessive surface zone ($>1000 \text{ m}^2/\text{g}$) and a high number of pores produce effective capacity of this component to cleaning of dentition and absorption of chromophores in oral cavity.^[10,14]

Greater space for the water molecules to diffuse into the polymeric network by degradation after AAA may contribute to lower color stability of resin composite.^[25] We believe that high potential of adsorbent of activated charcoal may absorb these water and degradation by products and influenced the optical properties of aged dental composite.

The abrasiveness of these toothpastes depends on their manufacturing process and the amount of carbon.^[15,26] In addition, Gb have some other abrasive components such as dicalcium phosphate dehydrate, thickener silica and abrasive silica. Dicalcium phosphate is a cleaning agent for natural teeth and dental composite.^[27] Another charcoal tooth paste also contains hydrated silica abrasive factor. Gp contains two kinds of surfactants such as sodium lauryl sulfate and cocamidopropyl betaine, which may make the hydrophobic agents available and distribute the toothpaste particles in the oral cavity. Therefore, presence of these two surfactants in the composition of Gp may increase the efficacy of its active components. These explanations may be contributing to discriminate the effect of these two charcoal toothpaste on color of aged composite. However, the abrasive particles in Go dentifrice and Gt are silica, calcium pyrophosphate and hydrated silica, respectively.

Since anti-calculus abrasive products containing phosphate do not have a favorable taste, higher amounts of flavor should be added to toothpastes with

higher amounts of abrasives. Therefore, Limonene has been added to the composition of Gp. The authors believe that Limonene may have greater effect on surface properties of aged composites due to its acidic nature, resulting in higher ΔE_2 .

Gt only contains hydrated silica and TiO_2 pigments, and sodium hydroxide to adjust its pH. As a result due to its higher pH and lower amounts of abrasives, the lowest color change of aged composite after brushing has been seen in this group (ΔE_2).

Colgate contains hydrogen peroxide and due to its synergistic effects with silica and tetra-sodium pyrophosphate, it ranked second in terms of color change of aged composite.

De Moraes Rego Roselino *et al.*,^[28] in an *in situ* study assessed the effect of whitening toothpastes on different composites in clinical setting and reported that different abrasive toothpastes had insignificant effect on color stability of composites.

Based on author's literature review, only three experimental studies were assessed the effect of whitening tooth pastes on the color of resin composite which were without staining and aging.^[2,15,18] Al-Shalan^[18] showed that the color change is related to the kind of restorative material and whitening tooth paste. The result of Roopa's research^[15] showed that a greatly significant color change was seen with whitening toothpaste after 2 weeks' usage in compomer and composites. While Hashemikamangar *et al.*^[2] showed in their research that toothpastes had no effect on the color of the composites, We cannot compare the results of these studies with our study, because they used composite samples without aging.

Changes in b^* parameter is associated with patient's satisfaction, in comparison to a^* and L^* parameters.^[10,16]

In charcoal toothpastes, the a^* and b^* parameters significantly decreased after toothbrushing while the L^* parameter significantly increased. In other words, samples with a shift to blue and green and their lightness increased after toothbrushing with these whitening toothpastes. However, the Δb_2 and Δa_2 in these groups had no significant difference with the corresponding values in other groups, which was in agreement with the results of de Moraes Rego Roselino *et al.*^[28] Limonene present in the composition of Gp has optical isomerism and may change the lightness (L^* parameter) to some extent.^[28] In the

control and Gt groups, the a^* , b^* and L^* parameters slightly changed after toothbrushing. This finding may be due to the fact that the only bleaching agents in the composition of Gt are hydrated silica and titanium oxide pigments, which do not significantly affect the color and lightness of composites discoloration after aging. However, in Go group, due to the presence of hydrogen peroxide with chemical mechanism of action, the b^* parameter significantly decreased while the L^* parameter significantly increased. It means that the yellowness of composites decreased and their lightness increased.

The efficacy of toothpastes depends on the distribution of particles in the toothpaste, their formulation, geometry of toothbrushes, filaments of toothbrushes, toothbrushing technique adopted by the operator and saliva secretion rate.^[11] In this study, a toothbrushing machine was designed to standardize the technique of tooth brushing and the concentration of toothpaste used. This was a strength of this study.

This study had some limitations that limited the generalization of results to the clinical setting. The composite samples were flat while the restoration surfaces follow the anatomical contour of the teeth in the clinical setting. Moreover, we diluted the toothpastes with distilled water which is different from the clinical setting (presence of saliva, enzymes, proteins, and ions).^[18] Furthermore, we did not have adequate knowledge about the size of particles and percentage of each toothpaste ingredient since the manufacturers do not clearly disclose the composition of their products.^[18] Last but not least, we only assessed one type of composite (bis-GMA based, microhybrid). Similar studies on other composite types and in presence of extrinsic stains in addition to AAA are required.

CONCLUSION

Within the limitations of this *in vitro* study, the results showed that there is no significant difference in the change of the color parameters of spectrum composite following tooth brushing with Gp, Gb, Gt and Go for two weeks. However, based on the compression of L^* , b^* and a^* parameters before and after tooth brushing, it became significantly lighter and showed a shift to blue and green after tooth brushing with charcoal toothpastes (Gp and Gb). In addition, it became significantly lighter and its yellowness decreased after the application of Colgate

Go. The color change caused by aging would not be perceivable by the human eye after tooth brushing with charcoal whitening toothpastes ($\Delta E < 3.3$).

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

REFERENCES

1. Kovacevic Pavicic D, Pavlic A, Kinkela Devcic M, Lajnert V, Spalj S. Tooth color as a predictor of oral health-related quality of life in young adults. *J Prosthodont* 2019;28:e886-92.
2. Hashemikamangar SS, Hoseinpour F, Kiomarsi N, Dehaki MG, Kharazifard MJ. Effect of an optical whitening toothpaste on color stability of tooth-colored restorative materials. *Eur J Dent* 2020;14:85-91.
3. Manis RB, Da Silva TM, Franco TT, Dantas DC, Franco LT, Huhtala MF. Influence of whitening toothpaste on color, roughness, and microhardness of composite resins. *Eur J Gen Dent* 2017;6:92-8.
4. Carey CM. Tooth whitening: What we now know. *J Evid Based Dent Pract* 2014;14 Suppl: 70-6.
5. Mills RW, Jandt KD, Ashworth SH. Dental composite depth of cure with halogen and blue light emitting diode technology. *Br Dent J* 1999;186:388-91.
6. Demarco FF, Meireles SS, Masotti AS. Over-the-counter whitening agents: A concise review. *Braz Oral Res* 2009;23 Suppl 1:64-70.
7. Matis BA, Cochran MA, Eckert G, Carlson TJ. The efficacy and safety of a 10% carbamide peroxide bleaching gel. *Quintessence Int* 1998;29:555-63.
8. Abdelmegid FY. Effect of whitening toothpastes on bonding of restorative materials to enamel of primary teeth. *Niger J Clin Pract* 2016;19:242-7.
9. Vertuan M, de Souza BM, Machado PF, Mosquim V, Magalhães AC. The effect of commercial whitening toothpastes on erosive dentin wear *in vitro*. *Arch Oral Biol* 2020;109:104580.
10. Vaz VT, Jubilato DP, Oliveira MR, Bortolato JF, Floros MC, Dantas AA, *et al.* Whitening toothpaste containing activated charcoal, blue covarine, hydrogen peroxide or microbeads: Which one is the most effective? *J Appl Oral Sci* 2019;27:e20180051.
11. Joiner A. Whitening toothpastes: A review of the literature. *J Dent* 2010;38 Suppl 2:e17-24.
12. Kleber CJ, Putt MS, Nelson BJ. *In vitro* tooth whitening by a sodium bicarbonate/peroxide dentifrice. *J Clin Dent* 1998;9:16-21.
13. Joiner A, Philpotts CJ, Alonso C, Ashcroft AT, Sygrove NJ. A novel optical approach to achieving tooth whitening. *J Dent* 2008;36 Suppl 1:S8-14.
14. Epple M, Meyer F, Enax J. A Critical Review of Modern

- Concepts for Teeth Whitening. Dent J (Basel) 2019;7:79.
15. Roopa KB, Basappa N, Prabhakar AR, Raju OS, Lamba G. Effect of whitening dentifrice on micro hardness, colour stability and surface roughness of aesthetic restorative materials. J Clin Diagn Res 2016;10:ZC06-11.
 16. Heshmat H, Hoorizad Gangkar M, Emami Arjomand M. Color stability of three composite resins following accelerated artificial aging: An in-vitro study. J Islam Dent Assoc Iran 2014;26:90-5.
 17. Greenwall-Cohen J, Francois P, Silikas N, Greenwall L, Le Goff S, Attal JP. The safety and efficacy of 'over the counter' bleaching products in the UK. Br Dent J 2019;226:271-6.
 18. Al-Shalan T. Effect of whitening toothpastes on color stability of different restorative materials. Int J Med Sci Clin Invent 2017;4:2790-6.
 19. Alharbi M, Farah R. Effect of water-jet flossing on surface roughness and color stability of dental resin-based composites. J Clin Exp Dent 2020;12:e169-e177.
 20. De Oliveira DC, Ayres AP, Rocha MG, Giannini M, Puppini Rontani RM, Ferracane JL, *et al.* Effect of different *in vitro* aging methods on color stability of a dental resin-based composite using CIELAB and CIEDE 2000 color-difference formulas. J Esthet Restor Dent 2015;27:322-30.
 21. Szczesio-Wlodarczyk A, Sokolowski J, Kleczewska J, Bociog K. Ageing of dental composites based on methacrylate resins A critical review of the causes and method of assessment. Polymers (Basel) 2020;12:882.
 22. Kutner MH, Nachtsheim CJ, Neter J. Applied Linear Statistical Models. 5th ed. McGraw-Hill/Irwin: New York, USA; 2004. p. 1343.
 23. Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent 2007;97:200-8.
 24. Farah RI, Elwi H. Spectrophotometric evaluation of color changes of bleach-shade resin-based composites after staining and bleaching. J Contemp Dent Pract 2014;15:587-94.
 25. Drubi-Filho B, Garcia Lda F, Cruvinel DR, Sousa AB, Pires-de-Souza Fde C. Color stability of modern composites subjected to different periods of accelerated artificial aging. Braz Dent J 2012;23:575-80.
 26. Robinson FG, Rueggeberg FA, Lockwood PE. Thermal stability of direct dental esthetic restorative materials at elevated temperatures. J Forensic Sci 1998;43:1163-7.
 27. Ali S, Farooq I, Shahid F, Hassan U, Zafar MS. Common toothpastes abrasives and methods of evaluating their abrasivity. J Oral Res 2020:84-90.
 28. de Moraes Rego Roselino L, Tonani Torrieri R, Sbardelotto C, Alves Amorim A, Noronha Ferraz de Arruda C, Tirapelli C, *et al.* Color stability and surface roughness of composite resins submitted to brushing with bleaching toothpastes: An *in situ* study. J Esthet Restor Dent 2019;31:486-92.