Original Article

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Exposure to coffee and bleaching altered surface treated lithium disilicate porcelain color and surface roughness

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Objective: This study evaluated the color and surface roughness change in autoglazed and overglazed, with or without polishing, IPS e.max Press (Ivoclar Vivadent AG,Schaan,Liechtenstein) after exposure to coffee and a bleaching agent.

Materials and methods: Ninety-six specimens (10x10x2 mm^3) were separated into 4 groups (n=24); polished autoglazed (PA), unpolished autoglazed (UA), polished overglazed (PO) , and unpolished overglazed (UO). The polished specimens were prepared using a porcelain adjustment kit (SHOFU®, Kyoto, Japan) according to the manufacture's instruction. The IPS e.max Press specimens were sent to a dental laboratory for glazing. Each group was divided into 2 subgroups; 1. Control group-The control group was immersed in distilled water. The color value changes was evaluated using a spectrophotometer (Ultrascan Pro, Hunterlab) before and after being immersed in distilled water and 2. Coffee group- exposed to coffee (Nescafe Red Cup ®, Bangkok Thailand) for 45 days before bleaching with 35% carbamide peroxide gel (Opalescense ® 35% PF). The color and surface roughness value changes were evaluated using a spectrophotometer and surface roughness tester (Alicona,Itasca,USA) respectively, before and at 45 days of coffee immersion and after bleaching. The SPSS 24 statistical software was used for analyzing the data. The paired-T test was applied to determine significant differences in color and surface roughness changing of the IPS e.max Press surface treatment groups and analysis of variance using the F-test if the results showed a normal distribution.

Results: There was a significant difference in the color change in all surface treatment groups after bleaching. There was no significant difference in color between the polished and unpolished groups. Comparing the autoglazed and overglazed groups, there were significant differences only between the unpolished groups. There was a significant difference in the surface roughness value in all groups, except between the exposed to coffee and exposed to the bleaching agent in the unpolished group and between the initial and exposed to coffee in the overglazed group.

Conclusions: Exposure to coffee and water affected the color change of all groups. Exposure to coffee affected the surface roughness of the autoglazed group. Bleaching affected the color change of coffee groups and affected the surface roughness of the polished autoglazed and polished overglazed groups. In the polished autoglazed and polished overglazed groups, glazing did not affect the color change, but affected the surface roughness.

Keywords: bleaching, coffee, color changes, IPS e.max Press, surface roughness

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Introduction

Currently, tooth-colored restorations are typically placed for esthetic reasons. Some studies reported that tooth-colored restorations can be stained by foods and beverages, especially coffee [1]. Drinking coffee has become more popular since 1999 in America [2]. Tooth bleaching

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has become popular and is often requested by patients who want to improve their tooth shade [1]. Joiner 2006 [3] reported that tooth whitening occurs via oxidation of peroxide that diffuses through the enamel to form lighter colored molecules. There are many types of bleaching techniques, such as in-office bleaching (power bleaching), home bleaching (dentist-supervised nightguard bleaching), and over-the-counter bleaching [4-7].

Among the tooth-colored restorations, resin composite, ceramic, and glass-ionomer cement, porcelain veneers have become a popular conservative esthetic restoration treatment choice for anterior teeth, due to their natural appearance, good wear resistance, and color stability [8, 9]. Porcelain is considered to be color stable and resistant to external stainings. However, several studies have revealed that staining drinks and bleaching caused changes in color and increased the surface roughness of this material.but some study revealed that bleaching do not effect the surface roughness of the ceramic [8-15]

The purpose of this study was to evaluate the change in the color and surface roughness of autoglazed and overglazed, with or without polishing, lithium disilicate glass ceramic (IPS e.max Press) after being exposed to coffee and a bleaching agent.

Materials and Methods

Specimen preparation

Ninety-six specimens were fabricated using the following method: blue inlay wax was melted into a metal mold. The upper surface of the wax was smoothened by pressing a heated glass slide on the top of the metal mold. The wax patterns were processed into IPS e.max Press ceramic. (Figure1)

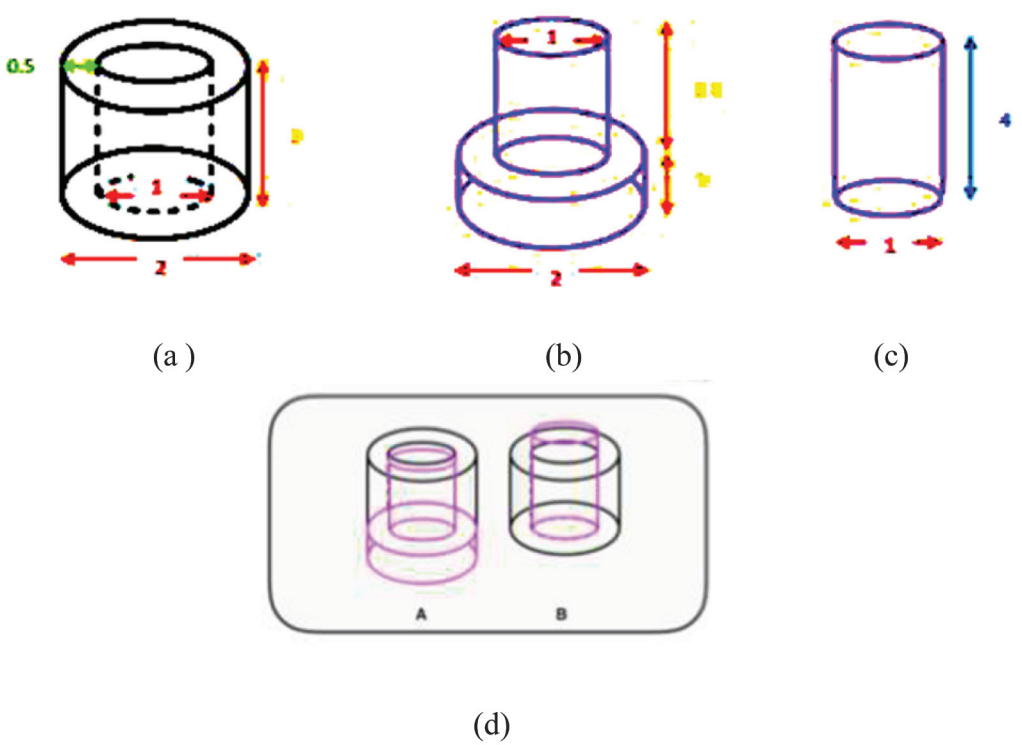

Figure1 Metal mold design (a) size of the outer component (centimeters), (b,) size of the short inner component (centimeters), (c) size of the long inner component (centimeters), and (d) outer component with long inner component (A) and short inner component (B).

Color and surface roughness evaluation

Ninety-six specimens (10x10x2 mm^3) were separated into 4 groups (n=24); polished autoglazed (PA), unpolished autoglazed (UA), polished overglazed (PO), and unpolished overglazed (UO). To polish the porcelain in the 2 subgroups, polished autoglazed and polished overglazed, a porcelain adjustment kit (SHOFU®, Japan) was used according to the manufacturer's instruction. The IPS e.max Press specimens were sent back to a dental laboratory for glazing. The specimens were evaluated for initial color and roughness values using a spectrophotometer (Ultrascan Pro, Hunterlab) and a non-contact surface roughness tester (Alicona, Itasca, USA), respectively. In the control group, forty-eight specimens were immersed in distilled water, and the experimental group (forty-eight specimens) were immersed in 250 ml coffee in a 37°C incubator [16]. The coffee was prepared by mixing 30 g of coffee powder (Nescafe Red Cup ®, Bangkok Thailand) 1 L of boiling distilled water simmered for 5 min and then filtered through a filter paper.The distilled water and coffee were changed every 7 d. On day 45, the specimens were washed with distilled water 10 times and wiped dry with tissue paper before the color and surface roughness were evaluated. The experimental was then bleached on one surface with 35% carbamide peroxide gel (Opalescence® 35% PF) for 1 h, to simulate an in-office bleaching treatment. The specimens were cleaned with distilled water, their surface roughness and color change was determined. The color change was evaluated using a spectrophotometer and surface roughness was evaluated with a non-contact surface roughness tester. The Novascan program was used to analyze the color matching of the porcelain. Statistical software SPSS 24 was usedto analyze the data. The paired-T test was used to determine significant difference in 2 samples in color and surface roughness changing of IPS e.max Press and analysis of variance with F-test if the result showed a normal distribution.

Results

The lithium disilicate ceramics (IPS e.max Press) demonstrated a color change (ΔE) when exposed to coffee and the bleaching agent (Table 1). Within each surface treatment group, there were no significant differences between the initial-water group (control, In-W) and initial-coffee group (In-C). However, there were significant differences in ΔE in the surface treatment groups between the initial-coffee group (In-C) and coffee-bleaching group (C-B). (Table1) (Figure2)

Table 1 Mean and standard deviation of color change values

Test / Surface treatment	Color change (ΔE) (Mean ± SD)		
	Initial – Water (Controlled,In-W) (each group,n=12)	Initial – Coffee (In-C) (each group,n=12)	Coffee –Bleaching (C-B)
Polished autoglazed (PA)	8.69 ± 0.32	9.02 ± 0.75 *	* 0.70 ± 0.33
Unpolished autoglazed (UA)	8.40 ± 0.98 *	9.31 ± 0.47 *	* 1.34 ± 1.03
Polished overglazed (PO)	9.02 ± 0.89	9.27 ± 0.71 *	* 1.87 ± 0.72
Unpolished overglazed (UO)	9.41 ± 0.87 *	9.31 ± 0.64 *	* 1.76 ± 1.03

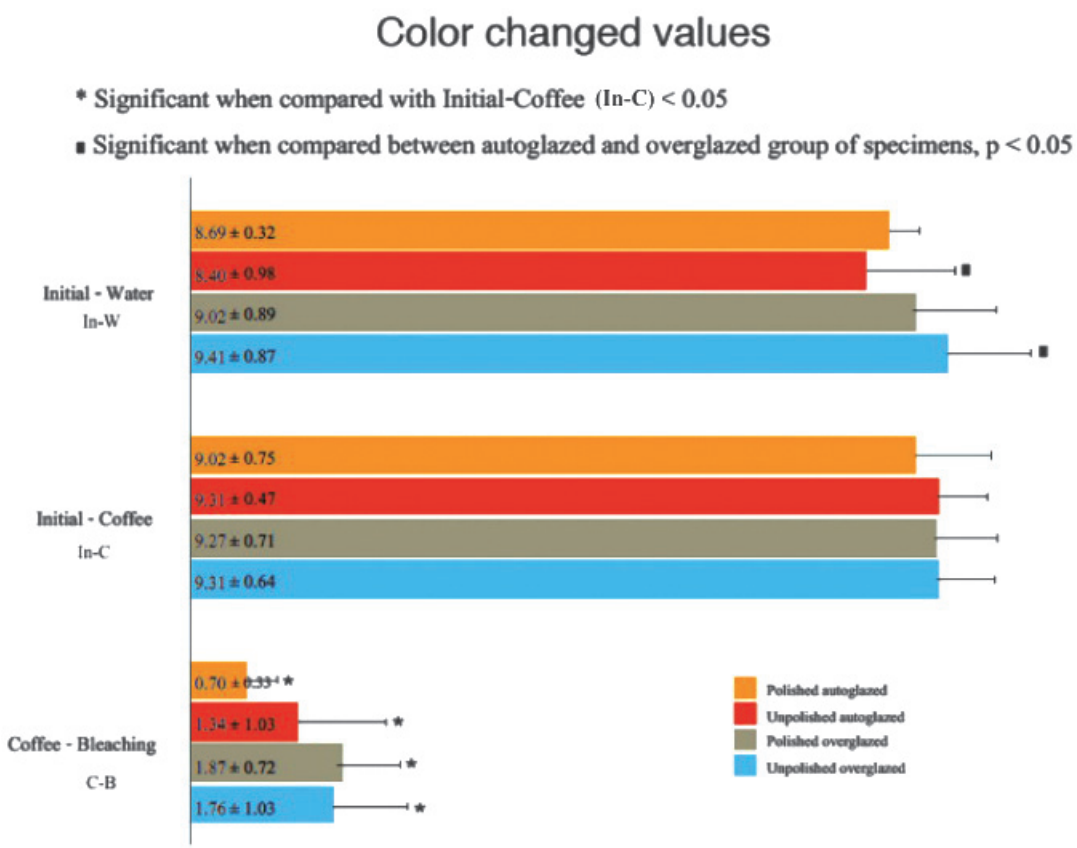

Figure 2 Illustrated graph shows mean and standard deviation of color change value

The ΔE of each surface treatment group was also evaluated within each exposure group. The results indicate that there was no significant difference in ΔE in the polished and unpolished IPS e.max Press surface treatment groups between exposure groups. In addition, the ΔE in the autoglazed and overglazed IPS e.max Press groups was only significantly different in the control group (In-W).

The surface roughness within each surface treatment group was determined (Table 2) (Figure3). We found that the surface roughness values (Ra) of the polished autoglazed group (PA) were significantly different between the initial group and exposed to coffee, exposed to coffee and exposed to bleaching agent groups, and the initial and exposed to bleaching agent groups. In the unpolished autoglazed group (UA), there were significant differences in Ra between the initial and exposed to coffee groups, and the initial and exposed to bleaching agent groups. The polished overglazed group (PO) demonstrated significant differences between the exposed to coffee and exposed to bleaching agent groups, and the initial and exposed to bleaching agent groups. There were also significant differences the unpolished overglazed group (UO) Ra between the initial and exposed to bleaching agent groups. Comparing the surface roughness change (ΔRa) between the polished and unpolished IPS e.max Press groups illustrated that there was no significant differences in each exposure group except between the polished overglazed and unpolished overglazed groups in the initial-bleaching group (In-B) (Table 3) (Figure4). However, the ΔRa between the autoglazed and overglazed IPS e.max Press, comparing between group (UA) and group (UO) were not significantly different in all exposure groups. However, there were significant differences in ΔRa between group (PA) and group (PO) in the initial-coffee group (In-C) and initial-bleaching group (In-B).

Table 2 Mean and standard deviation of surface roughness values in coffee group.

Test / Surface treatment (each group,n=12)	Surface roughness value (Ra) (Mean ± SD)		
	Initial	Exposed to coffee	Exposed to bleaching agent
Polished autoglazed (PA)	0.91 ± 0.25 *	* 1.02 ± 0.33 *	* 1.14 ± 0.31
Unpolished autoglazed (UA)	0.90 ± 0.19 *	* 1.28 ± 0.41	1.50 ± 0.64
Polished overglazed (PO)	0.72 ± 0.05	0.72 ± 0.05 *	* 0.77 ± 0.04
Unpolished overglazed (UO)	0.92 ± 0.14	1.14 ± 0.30	1.28 ± 0.33

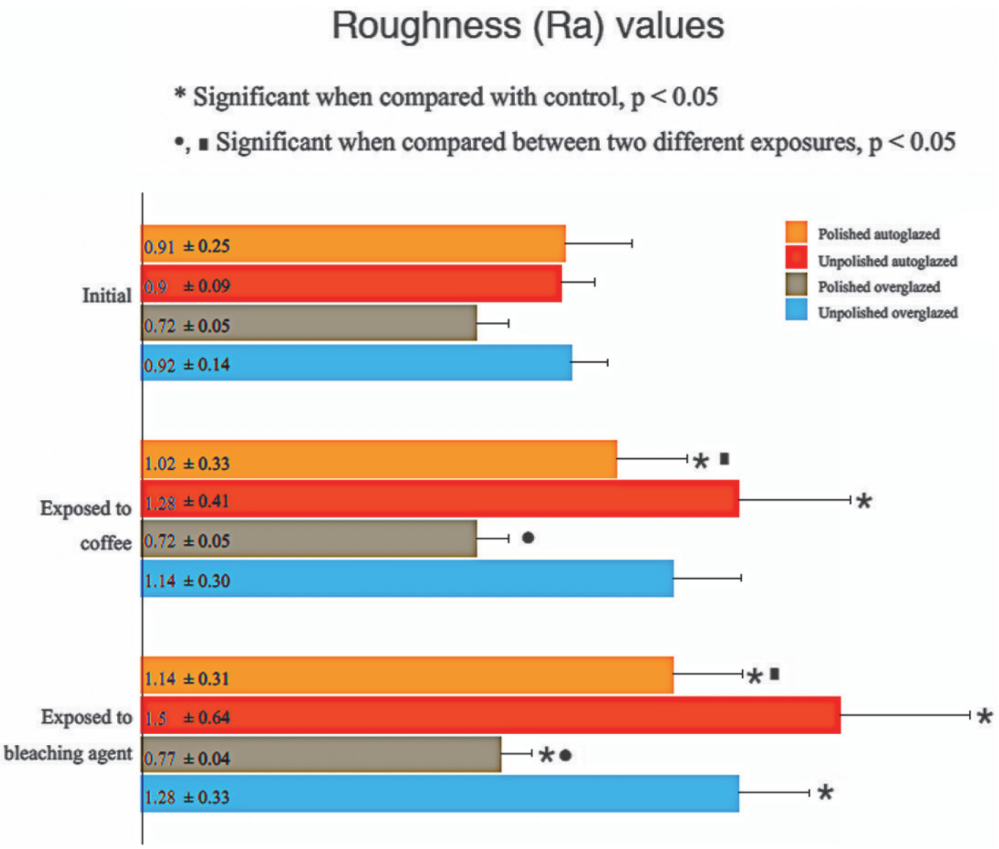

Figure 3 Illustrated graph shows mean and standard deviation of color change values in coffee group.

Table 3 Mean and standard deviation of surface roughness change values

Test / Surface treatment	Surface roughness change (ΔRa) (Mean ± SD)		
	Initial – Coffee (In-C) (each group,n=12)	Coffee - Bleaching (C-B) (each group,n=12)	Initial – Bleaching (In-B) (each group,n=12)
Polished autoglazed (PA)	0.13 ± 0.09	0.13 ± 0.09	0.23 ± 0.10
Unpolished autoglazed (UA)	0.38 ± 0.42 *	0.22 ± 0.38	0.61 ± 0.62 *
Polished overglazed (PO)	0.01 ± 0.03 *	0.05 ± 0.05	0.05 ± 0.05 *
Unpolished overglazed (UO)	0.22 ± 0.30	0.14 ± 0.22	0.36 ± 0.29

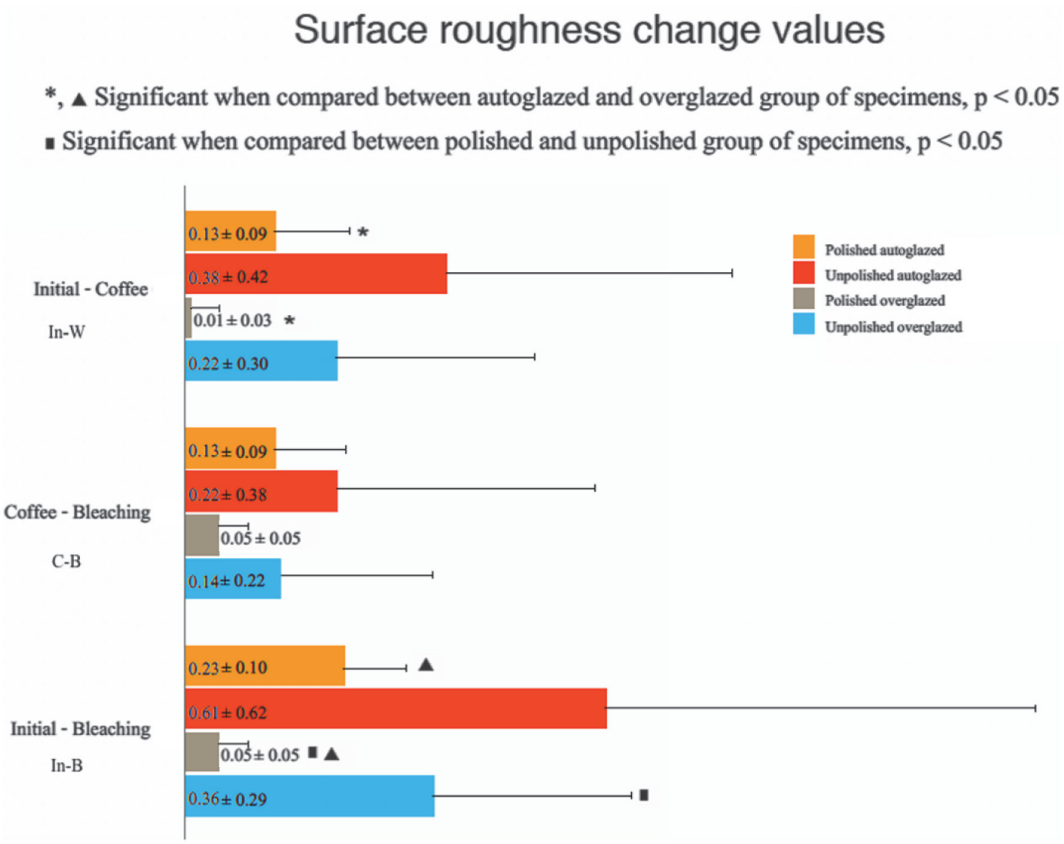

Figure 4 Illustrated graph shows mean and standard deviation of surface roughness change values.

Discussion

The results of the present study indicated that bleaching and immersing IPS e.max Press porcelain in coffee and water affected the color in every specimen group. These results corresponded with those of Gupta et al [1] concerning color change from coffee immersion. Their study evaluated the color stability of tooth-colored restorations, including porcelain, immersed in various colored beverages and evaluated using a spectrophotometer. Coffee was found to cause more discoloration in porcelain compared with the others beverages investigated [1]. Although there was no significant difference in ΔE in the control group, there was some degree of color change when IPS e.max Press was immersed in water. These results were unexpected because the color values in the control groups were anticipated to remain stable in this condition. However, Gawriolek et al. reported that there was a slight change in color when lithium disilicate ceramics were immersed in water for seventy hours [12]. Their study investigated the color and luminescence stability of selected dental materials in vitro, including IPS e.max Press. These materials were immersed in distilled water, coffee, tea, or red wine. They found that water induced some changes in the visual appearance of most of the materials evaluated [11]. Palla et al. also found similar results [12]. They suggested that a rough surface might allow penetration by water that dissolved the silica network. ,Subsequently, reduced crystallinity and increased coloring pigments absorption might occur [12]. In our study, the cause of color change in the control group may have occurred for the same reasons. We also found that there was no significant difference in color change between the coffee immersed and control groups. However, the color change values (ΔE) in both groups were

above the maximum value that the human eye cannot detect. Goldstein and Schmitt 1993 stated that a ΔE value greater than 0.4 could be detected by trained human eyes [17].

We found significant color changes in the bleaching groups after being exposed to the bleaching agent in all surface treatment groups. Our results coincided those of of Zaki and Fahmy. [10]. These authors found that bleaching whitened the porcelain, especially in the overglazed group compared with the autoglazed group [10].

One of the criteria we used for dividing the groups of specimens was surface polishing. Surface polishing is a procedure used clinically for reducing the surface roughness after ceramic restoration adjustment, so they retain less plaque and stain less [8, 10].

There are numerous studies that demonstrated that glazing and polishing provided equally smooth surfaces [18-21] Another study reported that in terms of visual perception, two different polishing pastes produced an equal or smoother surface compared with glazing [19-21]. In contrast, scanning electron microscopic (SEM) examination indicated that glazed surface was smoother [22]. Fuzzi et al ,demonstrated that glazing generated the best surface smoothness results compared with other methods evaluated using SEM [22]. They concluded that surface treatments affected the surface roughness and color stability. Different surface treatment methods caused different surface texture changes and related ceramic staining [22].

Zaki and Fahmy[10] compared autoglazed and overglazed groups after bleaching. They reported that the overglazed group had significantly increased the whiteness and the roughness compared to the autoglazed group. They also concluded that glazing had some effect on color change of porcelain when using bleaching [10].

Reddy et al.[24] evaluated the effect of commonly consumed beverages on the color stability and surface roughness of two metal ceramic materials, feldsparthic: IPS d.Sign-I and Ceramco 3. The acidic agents used in their study were coffee and cola with a pH of 5 and 2.4, respectively. They stated that the carbonic and citric acid in cola might dissolve elements in ceramics due to their chelating effect. The SEM and profilometer evaluation in their study revealed that the surface roughness of IPS d.Sign and Ceramco 3 significantly increased when immersed in coffee or cola for 90 d [24]. Our study found the same results, where the Ra values in the polished and unpolished autoglazed groups significantly changed after being immersed in coffee. These results might also be caused by acidic effect described in the previous study.

El-Murr et al.[25] found that bleaching affected the microhardness and surface roughness of autoglazed and overglazed porcelain by reducing the silicon dioxide (S_iO_2) and potassium peroxide (K_2O_2) molecule [10,26] In contrast, several laboratory studies evaluating in-office (38% HP) and at-home (15% CP) bleaching agents concluded that the ceramic restoration microhardness was not affected 30 days after the end of the bleaching procedure [13, 14]. The present study used 35% carbamide peroxide as a bleaching agent and found significant changed in surface roughness in most groups, especially in the polishing groups. These findings might be associated with reduced silicon dioxide (SiO2) and potassium peroxide (K2O2) molecules as mentioned above. Based on these results, bleaching is not recommended for IPS e.max Press, to avoid changes in restoration color and surface roughness.

Our study compared the color change values (ΔE) and surface roughness values (ΔRa) between the IPS e.max Press polished and unpolished groups. The results illustrated that there was no significant difference in all exposure conditions except between the initial and after bleaching Ra in the polished and unpolished overglazed groups. These results indicate that polishing had a non-significant effect on color staining and surface roughness changes, especially the surface

roughness change in the overglazed group when exposed to coffee and then bleaching.However, the polished specimens had equal or lower Ra values compared with the unpolished specimens. Therefore, the use of polishing procedures is still suggested.

The ΔE and ΔRa between the IPS e.max Press autoglazed and overglazed groups were not significantly difference in all tests except the ΔE between the unpolished autoglazed and unpolished overglazed in the control groups. The ΔRa in the polished autoglazed and polished overglazed groups were significantly different between the initial and coffee immersion, and initial and after bleaching groups These results showed that glazing had less influence on color change, however, it had significant effect to the change in surface roughness of specimens in most tests. The overglazed groups also showed less change in surface roughness when immersed in coffee and exposed to bleaching agent. In conclusion, dental practitioners should select overglazing IPS e.max Press for coffee consumers to lengthen the life time of the prosthesis.

The Ra values after coffee immersion and after bleaching indicated that there were significant changes of Ra values in the polished autoglazed and overglazed groups. In contrast, there was no significant change in both unpolished groups. These results might be due to the dissolvability of the bleaching agent and the initial surface roughness of the unpolished specimens that had a rougher surface with more exposed filler particles at the beginning before exposure to coffee or the bleaching agent. While polished specimens had smoother surface roughness at the beginning.

We used only coffee to investigate the color change in our study. We did not include other beverages that might give different results in color change. Currently, there are many other beverages that are commonly drunk and might stain dental prostheses. Future studies should include these types of beverages.

Conclusion

For IPS e.max Press, immersion either in water or coffee caused a non-significant color change. However, the color change values (ΔE) of both groups were greater compared with the maximum value that cannot be detected by human eye.

There were significant increase in surface roughness in the polished and unpolished autoglazed groups after being immersed in coffee.

There were significant color changes in the bleaching groups after being exposed to the bleaching agent in all surface treatment groups. The bleaching agent also significantly affect the changed of surface roughness in the polished autoglazed and polished overglazed groups. Based on the ΔE and ΔRa results, bleaching is not recommended for IPS e.max Press ceramic restorations because this affect color and surface roughness change of the restorations.

Comparing the polished and unpolished specimens, the polished specimens had an equal or less Ra values when evaluated after coffee immersion and bleaching. Therefore, polishing is still suggested for clinical use.

Because overglazed groups showed less change in surface roughness when immersed in coffee and exposed to bleaching agent, overglazing procedure should be selected to avoid increased surface roughness in the future.

Suggestion

Because this was an in-vitro study, the simulated situation of coffee exposure and applying a bleaching agent applying might not be the same as in the oral cavity. Moreover, the present study evaluated only IPS e.max Press ceramic and coffee immersion. Other ceramic restorations and beverages might not give the same results. Other types of ceramics, other acidic beverages, whitening toothpastes, and other bleaching agents should be included in

future studies. The use of artificial saliva and thermocycling should be considered to simulate the oral environment in subsequent studies.

Clinical implication

From our study, water and coffee likelyalter the color of a prosthesis made from IPS e.max Press after time in the mouth. This information should be given to the patients to raise their awareness of the potential for this change. If a color change occurs, although bleaching can whiten the restoration, it is not recommended to use clinically to restore the previous color of a porcelain restoration. Bleaching increased the surface roughness, which makes the restoration susceptible to plaque accumulation.

References

1. Gupta R, Parkar H, Shah N, and Jain V. A Spectrophotometric Evaluation of Color Changes of Various Tooth Colored Veneering Materials after Exposure to Commonly Consumed Beverages. *JIPS* 2005; 5(2): 72-8.
2. The National Coffee Association of USA. National Coffee Drinking Trends 2016. Newyork.
3. Joiner A. The Bleaching of Teeth: A Review of the Literature. *J Dent* 2006; 34: 412-19.
4. Yu H, Zhang CY, and Cheng SL. Effects of Bleaching Agents on Dental Restorative Materials: A Review of the Literature and Recommendation to Dental Practitioners and Researchers. *J Dent Sci* 2015; 10(4): 345-51.
5. Burrows S. A Review of the Efficacy of Tooth Bleaching. *Dent Update* 2009; 36: 537-51.
6. Sulieman MAM. An Overview of Tooth-Bleaching Techniques: Chemistry, Safety and Efficacy. *Periodontology 2000* 2008; 48: 148-69.
7. Perchyonok VT, and Grobler SR. Tooth-Bleaching: Mechanism, Biological Aspects and Antioxidants. *Int J Dent Oral Health* 2015; 1.3: 1-7.
8. Ourique SAM, et al. Effects of Different Concentrations of Carbamide Peroxide and Bleaching Periods on the Roughness of Dental Ceramics. *Braz Oral Res* 2011: 453-8.
9. Shenoy A, and Shenoy N. Dental Ceramics: An Update. *J Conserv Dent* 2010; 13: 195-203.
10. Zaki AA, and Fahmy NZ. The Effect of a Bleaching System on Properties Related to Different Ceramic Surface Textures. *J Prosthodont* 2009; 18: 223-9.
11. Gawriolek M, et al. Color and Luminescence Stability of Selected Dental Materials In Vitro. *J Prosthodont* 2012; 21: 112-22.
12. Palla ES, et al. Color Stability of Lithium Disilicate Ceramics after Aging and Immersion in Common Beverages. *J Prosthet Dent* 2018; 119: 1-11.
13. Polydorou O, Hellwig E, and Auschill TM. The Effect of Different Bleaching Agents on the Surface Texture of Restorative Materials. *Oper Dent* 2006; 31: 473-80.
14. Polydorou O, Monting JS, Hellwig E, and Auschill TM. Effect of In-Office Tooth Bleaching on the Microhardness of Six Dental Esthetic Restorative Materials. *Dent Mater* 2007; 23: 153-8.
15. Chandni Jain, Akshay Bhargava, Sharad Gupta, Rishi Rath, Abhishek Nagpaland Prince Kumar.Evaluation of the color changes of different feldspathic porcelains after exposure to commonly consumed beverages. *Eur J Dent* 2013 Apr-Jun; 7: 172–180
16. Lee HS, O'Mahony M. At What Temperatures Do Consumers Like to Drink Coffee?: Mixing Methods. *J Food Sci* 2002; 67: 2774-7.
17. Goldstein GR, and Schmitt GW. Repeatability of a Specially Designed Intraoral Colorimeter. *J Prosthet Dent* 1993; 69: 616-9.
18. Motro PFK, Kursoglu P, and Kazazoglu E. Effects of Different Surface Treatments on Stainability of Ceramics. *J Prosthet Dent* 2012; 108: 231-7.
19. Yılmaz C, Korkmaz T, Demirkoprulu H, Ergun G, and Ozkany. Color Stability of Glazed and Polished Dental Porcelains. *J Prosthet Dent* 2008; 17: 20-4.
20. Klausner LH, Cartwright CB, and Charbeneau GT. Polished versus Autoglazed Porcelain Surfaces. *J Prosthet Dent* 1982; 47: 157-62.
21. Turker SB, Biskin T. Effect of three bleaching agents on the surface properties of three different esthetic restorative materials.*J Prosthet Dent* 2003 May; 89: 466-73
22. Fuzzi M, Zaccheroni Z, and Vallania G. Scanning Electron Microscopy and Profilometer Evaluation of Glazed and Polished Dental Porcelain. *Int J Prosthodont* 1996; 9: 452-8.
23. Aakriti Singh, Bhaskar Sengupta1, Harinder Kuckrej, K. B. S. Kuckreja. In vitro Study to Compare Glazed and Polished Surfaces ofFeldspathic Porcelain and Comparing Three Different PolishingSystem. *Indian J Dent Sci* 2017; 9: S21-6.

24. Reddy NR et al. The Effect of Commonly Consumed Beverages on Colour Stability and Surface Roughness of Two Metal Ceramic Materials: An In-Vitro Study. *Journal of Dr NTR University of Health Sciences* 2018; 8: 31-8.
25. El-Murr J, Ruel D, and St-Georges AJ. Effects of External Bleaching on Restorative Materials: A Review. *J Can Dent Assoc* 2011; 77: 1-6.
26. Malkondu O, Yurdaguven H, Say EC, Kazazoglu E, and Soyman M. Effect of Bleaching on Microhardness of Esthetic Restorative Materials. *Oper Dent* 2011; 36: 177-86.