ORIGINAL ARTICLE
Essent Dent 2021; 1(1): 23-29
DOI: 10.5152/EssentDent.2021.21001

Polishing Systems on Surface Roughness and the Color Stability of Leucite-Reinforced Feldspathic Ceramic

Gamze PAKEN

Department of Prosthodontics, Uşak University, Faculty of Dentistry, Uşak, Turkey

Cite this article as: Paken G. Polishing systems on surface roughness and the color stability of leucite-reinforced feldspathic ceramic. *Essent Dent. 1*(1):23-29.

Abstract

Objective: The purpose of this in vitro study was to determine the effect of different polishing methods applied on the surface roughness and color stability of leucite-reinforced feldspathic ceramic.

Methods: The leucite-reinforced feldspathic ceramic slices were divided into 3 treatment groups and 2 control groups: 1 μm diamond polishing paste (P), silicon carbide polishing kit (PK), silicon carbide polishing kit followed by 1 μm diamond polishing paste, glazed control group, and roughened control group. The color changes (ΔE) of the specimens were recorded with a spectrophotometer. The surface roughness was evaluated by using an atomic force microscope (AFM) and scanning electron microscopy (SEM). The R_a and R_z values were statistically analyzed with Kruskal–Wallis and the Mann–Whitney U-tests. The Shapiro–Wilk, and one-way ANOVA tests were used for comparing ΔE.

Results: Significant ΔE (color difference) values were found between groups after they were immersed in coffee solution ($P < .05$). According to the R_a and R_z values, statistically significant difference was found between all treatments and the glazed and roughened control groups ($P < .05$).

Conclusion: Polishing techniques significantly affected the color of the leucite-reinforced feldspathic ceramic. After adjustment of the dental ceramic surface to remove the glaze, the polishing kit with paste application can be utilized.

Keywords: Ceramic, color change, polishing, surface roughness

Introduction

Ceramic materials are widely preferred among the currently available dental materials, owing to their superior mechanical and optical qualities. With recent improvements in computer-aided design and computer-aided manufacturing (CAD/CAM) systems, the variety of ceramic materials has increased, and it has become possible to obtain satisfying esthetic restorations that mimic the optical properties of natural teeth.[1-4]

The surface glaze layer on the ceramic restoration ideally should preserve its continuity in the oral cavity during the individual's lifetime.[5] The glaze layer may alter after commonly applied intra-oral applications aiming to re-establish function and esthetics. This causes a negative impact on the surface roughness of the material, reducing the structural resistance.[6,7] Surface roughness also affects the clinical success of restorations. This is because some disorders that diminish esthetics, such as plaque buildup, bacterial accumulation, gingivitis, periodontitis, and caries can occur after those alterations.[8] Therefore, polishing is recommended on the ceramic surface after minor adjustments.[9]

To date, many studies have investigated the effect of different porcelain surface-polishing techniques with the aim of achieving ideal smoothness as glazed ceramic surfaces. They have concluded that polishing techniques can be an alternative to glazing of ceramic restorations. According to those studies, a multitude of polishing tools can be applied, such as diamond

Corresponding author: Gamze Paken
e-mail: dt.gamzeozturk@gmail.com

Received: March 22, 2021
Accepted: October 19, 2021
Available Online Date: November 20, 2021

burs, silicon carbide papers, polishing wheels, porcelain polishing discs, and diamond pastes can be used to prevent or reduce the roughness that occurs after intraoral adjustment post-cementation and to attain a smooth surface.[4,10-15]

Color stability is another vital parameter for the long-term success of ceramic restorations, but this aspect may not be achieved on the rough surfaces that occur after minor adjustments and/or polishing.[16-18] A rough surface cannot reflect light to the high degree that a smooth surface can.[19] Color changes can be determined visually or with a device. By using color measurement devices such as spectrophotometers and colorimeters, it is possible to obtain more objective results and standardize them with numerical color expressions according to visual evaluation.[20,21]

Several studies have evaluated the surface roughness and color stability of different ceramics by using miscellaneous polishing systems.[5,13,15,18,22,23] However, there are limited data about the effect of different surface-finishing protocols and the final color change on leucite-reinforced glass ceramics. In this study, the effects of using different polishing methods on the surface roughness and color change of leucite-reinforced glass ceramic have been investigated.

The null hypotheses were:

(1) The polishing techniques are not effective in repairing the surface roughness of leucite-reinforced feldspathic glass ceramics.
(2) There would be no difference between polishing groups and the control group in terms of color change before and after coffee immersion.

Methods

The leucite-reinforced feldspathic ceramic blocks (GC Initial™ LRF Blocks, Tokyo, Japan) used in this study and 13 specimens (8 × 8 × 1 ± 0.2 mm) were obtained with a low-speed (200 rpm) diamond saw (IsoMet 1000; Buehler, Lake Bluff, IL) under continuous water cooling, at equal thickness. All samples were ground with gradient silicon carbide abrasive papers of grit 400, 600, and 1200 (Leco VP 100, Leco Instrumente GmbH, Germany) for standardization. The thickness of each specimen was measured and controlled with a digital micrometer (Mitutoyo Corporation, Tokyo, Japan). Each specimen's surface was glazed (VITA Akzent Glaze; VITA Zahnfabrik, Bad Säckingen, Germany). The glaze powder and liquid were mixed with a plastic spatula according to the manufacturer's instructions, and applied with a plastic applicator on the specimens. The surface of the specimens was checked before the polishing process. The specimens were divided into 3 treatment groups and 2 control groups, as follows: 1 μm diamond polishing paste (P), silicon carbide polishing kit (PK), silicon carbide polishing kit followed by 1 μm diamond polishing paste (PK+P), glazed positive control group, and roughened negative control group. In the glazed positive control group, no additional treatment was performed.

In the 3 treatment groups and the roughened negative control group, one side of the glaze layer was removed with diamond rotating burs (extra-fine, yellow band, 15 μm grit; Komet Group, Besigheim, Germany) at nearly 10 000 rpm under water cooling to simulate clinical adjustment. After 2 preparations, a new bur was selected. In the control groups, no application was performed on the glazed ceramic surfaces. In the first treatment group (P), the surfaces were polished with 1 μm diamond paste (DiaPolisher; GC, Tokyo, Japan) using a nylon bristle brush under 10 000 rpm pressure without water for 20 seconds. In the second treatment group (PK), a silicon carbide polishing kit (coarse, medium, fine; Drendel+Zweiling 3-Step Ceramic Polishing Kit; Kalletal, Germany) was applied on abraded surfaces for 60 seconds each. In the third treatment group (PK+P), the same silicon carbide polishing kit was applied on abraded surfaces for 60 seconds and then the surfaces were polished with the 1 μm diamond paste using a nylon bristle brush under 10 000 rpm pressure without water for 20 seconds. All applications were carried out by a single researcher (G.P.) according to the manufacturer's instructions.

The specimens were ultrasonically cleaned (CD-4800 Digital Ultrasonic Cleaner; Jeken, Dongguan, China) with distilled water for 10 minutes and dried for 30 seconds before the color was measured. Before coffee immersion, baseline color was measured with a digital spectrophotometer (VITA Easyshade; VITA Zahnfabrik, Bad Säckingen, Germany) on a standard white background ($L^*=90.9$, $a^*=0.3$, $b^*=4.9$). To prepare the coffee solution, 3.6 g coffee (Nescafe Classic; Nestle Turkey, Bursa, Turkey) was placed in 300 mL of hot water according to the manufacturer's suggested concentration and mixed with a spatula for 10 minutes. After filtration through filter paper, the specimens were immersed in the pigmenting solution at 37°C for 12 days, simulating 1 year of coffee consumption.[24] The solution was stirred every 3 days to provide homogeneity. After 12 days of immersion, the specimens were cleaned with tap water and dried tissue paper. The device was calibrated according to the manufacturer's instructions as before and the measurements were carried out at the center of each specimen by the same experienced investigator (G.P.). The $L^*a^*b^*$ color measurements were obtained 3 times from each sample. The color differences between groups were calculated by using the CIEDE2000 (ΔE_{00}) color difference formula, and the mean values were recorded:

After the color measurement, the surface roughness of 3 specimens from each group was analyzed using non-contact mode AFM (Nanoscope IV; Digital Instruments Veeco Metrology Group, Plainview, NY). The arithmetic roughness means (R_a) and averaged roughness depth (R_z) were attained at 3 random locations with an area of 20 × 20 μm. One randomly selected specimen from the roughened-negative and glazed-positive control groups and one from each treatment group were investigated with SEM (EVO LS,10 SE, Zeiss, Germany) at a magnification of 100×.

Table 1.
The Mean and Standard Deviation Values of ΔE Color Difference Before and After Coffee Immersion of All Groups

	Groups	ΔE	SD
Before coffee immersion	P	2.85	0.19
	PK	2.63	0.22
	PK+P	2.01	0.17
After coffee immersion for 12 days	P	3.37	0.18
	PK	3.12	0.22
	PK+P	2.15	0.25
	Glazed control	0.86	0.26

According to the previous study, the effect size $D=0.62$ was assumed.[25] With a power analysis at a level of 0.05% and 80% power, the required minimum sample size was $n=8$. The obtained data sets were analyzed using SPSS v22 (IBM Corporation, Armonk, NY, USA) ($\alpha=0.05$). The Shapiro–Wilk test was applied to check for normality, and it was found that some data were not normally distributed ($P > .05$). The Kruskal–Wallis test was used to identify significant differences in R_a and R_z values, and the Mann–Whitney U-test was used for comparisons between groups. The ΔE values were statistically analyzed with the Shapiro–Wilk test to define normality and the significance of difference between groups was determined by one-way ANOVA, followed by the Bonferroni test ($P < .05$).

Results

The mean and standard deviation values of Δ*E* before and after coffee immersion of all groups have been shown in Table 1 ($P < .05$). No significant AE was found between all treatment groups in the color measurements recorded immediately after the specimen's surface polishing ($P > .05$). According to the one-way ANOVA results of this study, a significant difference was observed between the control group (Δ*E*=0.86) and the other polishing groups in the Δ*E* values after immersion in the coffee solution for 12 days (Table 2). While there was no significant difference between the diamond paste (P) (Δ*E*=3.37) and the polishing kit group (PK) (Δ*E*=3.12), significantly, the lowest ΔE values were found in the group treated with the polishing kit with the diamond paste (PK+P) (Δ*E*=2.15) compared to the other treatment groups.

The mean R_a and R_z values for all groups according to the AFM are shown in Table 3. The difference among the R_a and R_z values of polishing systems was not statistically significant ($P = .45$). According to the R_a and R_z values, statistically significant difference was found between all treatments and the glazed and roughened control groups ($P < .05$) (Table 4). However, neither P nor PK nor PK+P was able to achieve smoother surfaces than the glazed-positive control group (Figure 1A-E).

Table 2.
One-Way ANOVA Results for ΔE Values after Coffee Immersion

	Sum of Squares	*df*	Mean Square	F	Sig.
Between Groups	33.892	3	11.297	25.255	0.000
Within Groups	16.104	36	.447		
Total	49.995	39			

Table 3.
Mean and Standard Deviation of R_a and R_z Values with Various Surface Polishing Protocols (μm)

	PK	P	PK+P	Glazed Control (Positive)	Roughened Control (Negative)
Average roughness (R_a)	0.22 ± 0.05	0.30 ± 0.08	0.17 ± 0.10	0.02 ± 0.00	0.43 ± 0.06
Ten-point height (R_z)	1.16 ± 0.40	1.47 ± 0.17	1.11 ± 0.39	0.14 ± 0.09	1.71 ± 0.40

After polishing, the differences were observed both visually and with SEM. Consistent with visual evaluation, the SEM analysis showed that all polishing systems had a statistically significant effect and flattened the surface roughness after roughening with the bur. The PK+P group showed the lowest surface roughness values among all tested groups. In the P group, higher R_a and R_z values were found, but there was no statistically significant difference for the other treatment groups (Figure 2A-E).

Discussion

In the present study, the effect of polishing techniques on surface roughness of leucite-reinforced feldspathic ceramic blocks and the color change after coffee immersion were investigated. In the color difference measurement, the Δ*E* values were calculated. In this study, a value of $\Delta E > 3.0$ was considered an unacceptable color threshold. While there was a significant difference in Δ*E* values after polishing between all the treatment groups and the control group, there was no significant color difference among the treatment groups. A significant difference was observed between the control group and the other polishing groups in the Δ*E* values after immersion in coffee solution for 12 days. While there was no significant difference between the diamond paste (P) (Δ*E*=3.37) and polishing kit group (PK) (Δ*E*=3.12), significantly lower Δ*E* values were found in the polishing kit with diamond paste group (PK+P) (Δ*E*=2.15). These results were similar to those obtained in the study by Yıldırım et al.[26] According to the AFM results, the difference between the R_a and R_z values of the polishing systems was not found to be statistically significant. The R_a and R_z values obtained for the P group were shown to indicate higher roughness than

Table 4.
The Kruskal–Wallis Test Results of R_a and R_z Values Among Groups

	Test Statistics		
	Average Roughness (R_a)	Ten-Point Height (R_z)	*P*
Chi-square	23.478	11.081	
df	4	4	<.05
Asymp. Sig.	.000	.026	

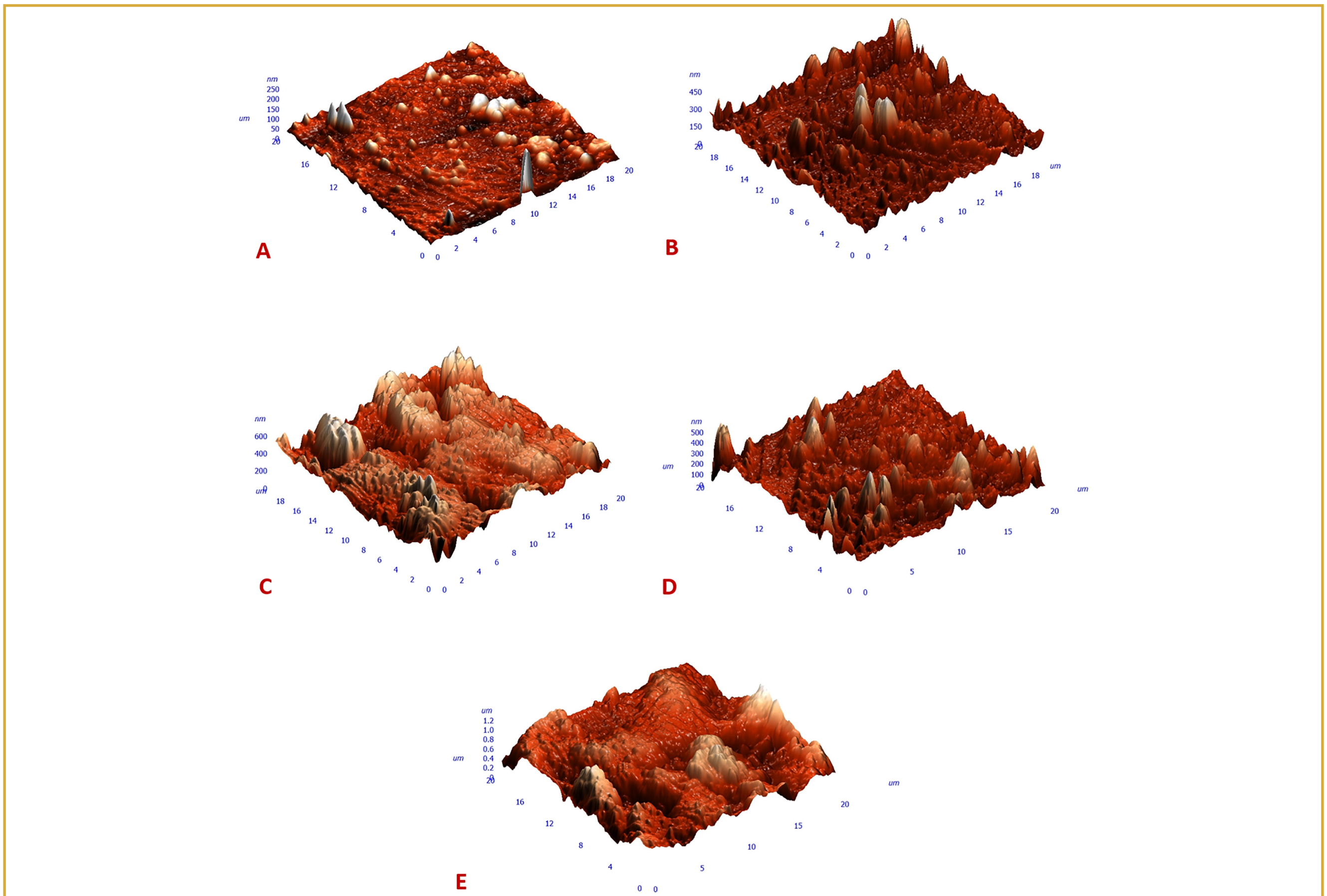

Figure 1. Atomic force microscope images of specimens after polishing. (A) Glazed positive control group. (B) Polishing kit group (PK). (C) Diamond polishing paste group (P). (D) Polishing kit + polishing paste group (PK+P). (E) Roughened negative control group.

the PK and PK+P groups. The PK+P group demonstrated the lowest surface roughness value. The results obtained from this present study exhibited that polishing processes applied on ceramic surfaces are effective on the roughened ceramic surface but they are not as successful in terms of color stability as glaze. In this regard, the hypotheses of the study were partially rejected.

The results of this present study showed that the polishing techniques affected final color (P=.00). The use of PK+P demonstrated the lowest ΔE values when compared to the other treatment groups. The lowest ΔE values were found in the glaze control group (ΔE=0.86), and the PK+P (ΔE=2.15) group, respectively. The PK+P group exhibited clinically acceptable ΔE value values before and after immersion in the staining solution ($\Delta E < 3.0$). The ΔE values obtained from P and PK before staining were found to be below the clinically acceptable level. However, the ΔE values obtained from the P and PK were greater than 3.0 after coffee immersion. These values were regarded as visually perceptible. In accordance with the results of this study, specimens of both treatment groups had undergone color changes when immersed in coffee solution, and in conformity with previous studies, it was found that the greater the surface roughness values, the greater the recorded color differences (ΔE).[9,22] This could be attributed to the fact that individual parts of the specular beam would be reflected from the rough surface at different angles.[27]

Maciel et al.[22] examined the color change in the fluorapatite and lithium disilicate glass ceramics where the polishing kits and paste were applied after the 12-day immersion in the coffee solution, and found clinically acceptable color difference values with the use of the polishing kits (ΔE=0.56-3.94) ($\Delta E < 3.3$). In the study by Sarac et al.[15] color changes caused by the different polishing techniques applied, either combined or alone, to the feldspathic ceramic were examined and found to conform with this study result; higher ΔE values were obtained with the use of polishing paste alone compared to polishing kits with or without polishing paste (ΔE=1.1-3.3 approximately) ($\Delta E < 3.5$). Similarly, Sarıkaya et al.[17] tested the effect of different polishing methods on color change after 48-hour coffee staining on low-fusing and feldspathic porcelain materials and they

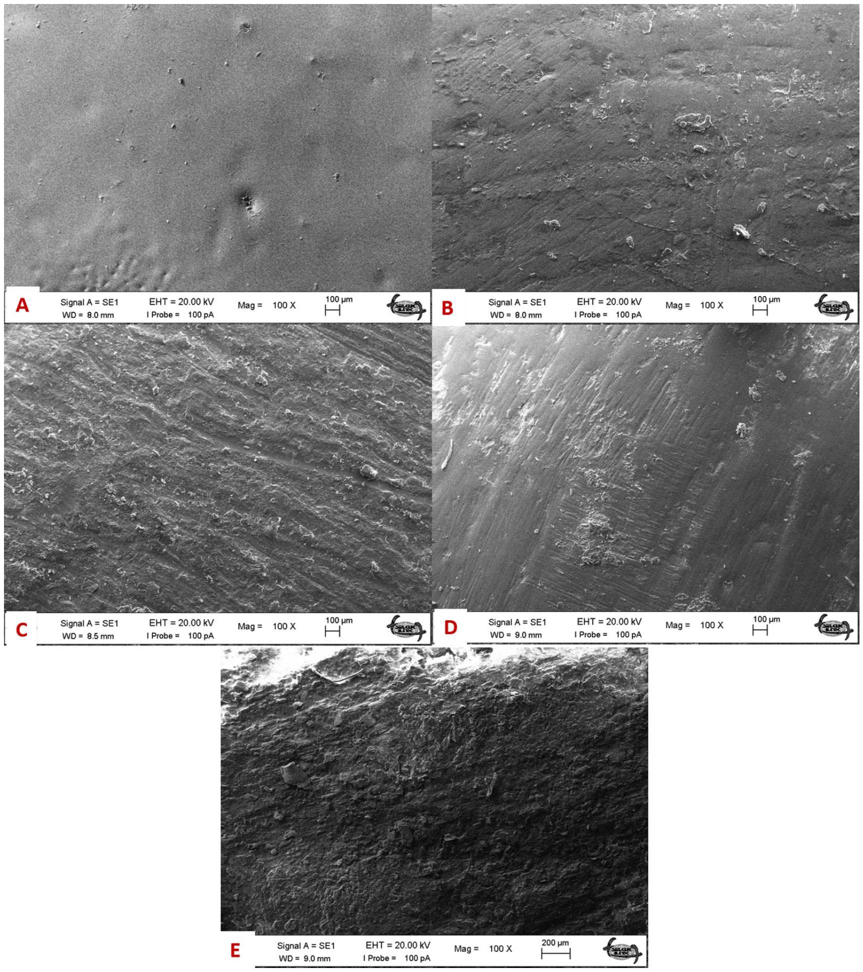

Figure 2. Scanning electron microscope images (original magnification ×100) of specimens after polishing. (A) Glazed positive control group. (B) Polishing kit group (PK). (C) Diamond polishing paste group (P). (D) Polishing kit + polishing paste group (PK+P). (E) Roughened negative control group.

suggested that polished specimens exhibited ΔE values ranging from 1.08 to 2.14 in all of the porcelain materials tested ($1 < \Delta E < 3.7$). The authors concluded that although the polishing techniques significantly affected the final color of the tested ceramics, the ΔE values were clinically acceptable. In this present study carried out on leucite-reinforced feldspathic ceramic, the PK+P group and the control group exhibited clinically acceptable ΔE values but the results of the P and PK result were greater than 3.0. This difference in results may be due to the variability of the clinically accepted ΔE reference values in color measurement studies.[22] The differences were also associated with differences in ceramic structure, polishing systems, and staining solution.

According to the AFM results, the samples in the P group were shown to have higher roughness values than those in the PK and PK+P groups. This study shows that polishing kits yield a surface which is almost as smooth as glazing when applied with a polishing paste. These results were also consistent with previous studies.[9,13,25] There were also studies that contrasted with this present study, which mentioned that polishing kits generated better surface smoothness than both polishing paste alone and in combination with polishing discs.[5,14] Furthermore, in the study by Yilmaz et al.[28] the effects of glaze, pastes, rubber discs, and abrasive paper on several ceramic systems were investigated and they found that the surface smoothness provided by glazing and pastes was clinically acceptable compared to that of the other groups. In this present study, it was concluded that in all treatment groups, the roughened ceramic surface could be polished to miscellaneous degrees, but none of them reached the glazed ceramic surface smoothness. Contrary to this study, other related studies indicated that polishing kits provided as much polishing as a glazed surface.[15,25,29,30] The differences might be explained by the use of different ceramic types, and the various brands of polishing kits tested in the studies.

In a study conducted on enamel surfaces, it was observed that ultrasonic and sonic instruments roughened the enamel more than fine diamond burs, and fine-grained burs are often used to eliminate occlusal defects in clinical practice.[31] Previous studies have concluded that 30 μm diamond rotating burs made the surface much rougher and polishing with high-speed headpieces at 20 000 rpm weakened the ceramic specimens.[32,33] In this study, the ceramic surfaces were abraded with a 15 μm diamond rotating bur, and the working speed of the rotary instrument was set at 10 000 rpm during the polishing kit application to reflect clinical practice.

The profilometer and the AFM are the most commonly used instruments in studies evaluating surface roughness. One study showed that the AFM gave reliable results in evaluating surface irregularity.[25] Detection with AFM provides higher resolution with a three-dimensional view and also gives more detailed results than other examination techniques such as a profilometer or visual evaluation, and more comprehensive results were obtained when SEM was used with AFM.[23,29] In this present study, both the AFM and the SEM were used to detect the surface roughness of ceramic surfaces after polishing.

In this study, only a single type of ceramic, polishing kit and staining agent were tested. Different outcomes might have been attained with different polishing materials and techniques. Future studies should investigate several ceramic materials and polishing methods. Further studies are needed to evaluate the surface roughness and color change of the leucite-reinforced feldspathic ceramic blocks after polishing with different polishing materials and techniques, using several solutions.

Conclusion

Within the limitations of this in vitro study:

1. The polishing methods applied in this study were effective on roughened ceramic surfaces. After polishing, the differences were observed both visually and with AFM and SEM. Furthermore, neither polishing paste nor polishing kits, nor the application of both were able to achieve outcomes as satisfactory as with glaze from the standpoint of surface roughness and color stability.
2. The polishing kit applied with polishing paste yielded clinically acceptable ΔE values, but in the other groups, the values were higher than 3.0. Those ΔE values were regarded as indicating visual perception.

The results of this study indicate that the polishing kit applied with polishing pastes on leucite-reinforced feldspathic ceramics may be clinically applicable in terms of surface roughness and color stability. Therefore, using appropriate polishing techniques for each type of ceramic can provide esthetically beneficial results for clinicians.

Ethics Committee Approval: No ethical approval was needed.

Informed Consent: No informed consent form was required.

Peer Review: Externally peer-reviewed.

Conflict of Interest: The author has no conflict of interest to declare.

Financial Disclosure: The author declared that this study has received no financial support.

References

1. Turgut S, Bagis B. Effect of resin cement and ceramic thickness on final color of laminate veneers: an in vitro study. *J Prosthet Dent*. 2013;109(3):179-186. [CrossRef]
2. Alp G, Subasi MG, Johnston WM, Yilmaz B. Effect of surface treatments and coffee thermocycling on the color and translucency of CAD-CAM monolithic glass-ceramic. *J Prosthet Dent*. 2018;120(2):263-268. [CrossRef]
3. Arif R, Yilmaz B, Johnston WM. In vitro color stainability and relative translucency of CAD-CAM restorative materials used for laminate veneers and complete crowns. *J Prosthet Dent*. 2019;122(2):160-166. [CrossRef]
4. Sen N, Us YO. Mechanical and optical properties of monolithic CAD-CAM restorative materials. *J Prosthet Dent*. 2018;119(4):593-599. [CrossRef]
5. Boaventura JM, Nishida R, Elossais AA, et al. Effect of finishing and polishing procedures on the surface roughness of IPS Empress 2 ceramic. *Acta Odontol Scand*. 2013;71(3-4):438-443. [CrossRef]
6. Al-Wahadni A, Martin DM. Glazing and finishing dental porcelain: a literature review. *J Can Dent Assoc*. 1998;64(8):580-583.
7. Rashid H. The effect of surface roughness on ceramics used in dentistry: a review of literature. *Eur J Dent*. 2014;8(4):571-579. [CrossRef]
8. Aykent F, Yondem I, Ozyesil AG, Gunal SK, Avunduk MC, Ozkan S. Effect of different finishing techniques for restorative materials on surface roughness and bacterial adhesion. *J Prosthet Dent*. 2010;103(4):221-227. [CrossRef]
9. Motro PF, Kursoglu P, Kazazoglu E. Effects of different surface treatments on stainability of ceramics. *J Prosthet Dent*. 2012;108(4):231-237. [CrossRef]
10. Sulik WD, Plekavich EJ. Surface finishing of dental porcelain. *J Prosthet Dent*. 1981;46(2):217-221. [CrossRef]
11. Haywood VB, Heymann HO, Kusy RP, Whitley JQ, Andreaus SB. Polishing porcelain veneers: an SEM and specular reflectance analysis. *Dent Mater*. 1988;4(3):116-121. [CrossRef]
12. Raimondo RL, Jr, Richardson JT, Wiedner B. Polished versus autoglazed dental porcelain. *J Prosthet Dent*. 1990;64(5):553-557. [CrossRef]
13. Karan S, Toroglu MS. Porcelain refinishing with two different polishing systems after orthodontic debonding. *Angle Orthod*. 2008;78(5):947-953. [CrossRef]
14. Fasbinder DJ, Dennison JB, Heys D, Neiva G. A clinical evaluation of chairside lithium disilicate CAD/CAM crowns: a two-year report. *J Am Dent Assoc*. 2010;141(suppl 2):10S-4S.
15. Sarac D, Sarac YS, Yuzbasioglu E, Bal S. The effects of porcelain polishing systems on the color and surface texture of feldspathic porcelain. *J Prosthet Dent*. 2006;96(2):122-128. [CrossRef]
16. Heydecke G, Zhang F, Razzoog ME. In vitro color stability of double-layer veneers after accelerated aging. *J Prosthet Dent*. 2001;85(6):551-557. [CrossRef]
17. Sarikaya I, Güler AU. Effects of different surface treatments on the color stability of various dental porcelains. *J Dent Sci*. 2011;6(2):65-71. [CrossRef]
18. Sarıkaya I, Yerliyurt K, Hayran Y. Effect of surface finishing on the colour stability and translucency of dental ceramics. *BMC Oral Health*. 2018;18(1):40. [CrossRef]
19. Obregon A, Goodkind RJ, Schwabacher WB. Effects of opaque and porcelain surface texture on the color of ceramometal restorations. *J Prosthet Dent*. 1981;46(3):330-340. [CrossRef]
20. Lee YK, Yu B, Lee SH, Cho MS, Lee CY, Lim HN. Variation in instrument-based color coordinates of esthetic re-storative

materials by measurement method: a review. *J Prosthet Dent*. 2011;26(1):47.
21. Seghi RR, Johnston WM, O'Brien WJ. Spectrophotometric analysis of color differences between porcelain systems. *J Prosthet Dent*. 1986;56(1):35-40. [CrossRef]
22. Maciel LC, Silva CFB, de Jesus RH, Concílio LRDS, Kano SC, Xible AA. Influence of polishing systems on roughness and color change of two dental ceramics. *J Adv Prosthodont*. 2019;11(4):215-222. [CrossRef]
23. Sarikaya I, Güler AU. Effects of different polishing techniques on the surface roughness of dental porcelains. *J Appl Oral Sci*. 2010;18(1):10-16. [CrossRef]
24. Guler AU, Yilmaz F, Kulunk T, Guler E, Kurt S. Effects of different drinks on stainability of resin composite provisional restorative materials. *J Prosthet Dent*. 2005;94(2):118-124. [CrossRef]
25. Incesu E, Yanikoglu N. Evaluation of the effect of different polishing systems on the surface roughness of dental ceramics. *J Prosthet Dent*. 2020;124(1):100-109. [CrossRef]
26. Yıldırım B, Recen D. Color stability and translucency of two CAD-CAM restorative materials subjected to mechanical polishing, staining, and prophylactic paste polishing procedures. *J Ege Univ School Dent*. 2021;42(1):1-8.
27. Lee Y-K, Lim B-S, Kim C-W. Effect of surface conditions on the color of dental resin composites. *J Biomed Mater Res*. 2002;63(5):657-663. [CrossRef]
28. Yılmaz K, Özkan P. Profilometer evaluation of the effect of various polishing methods on the surface roughness in dental ceramics of different structures subjected to repeated firings. *Quintessence Int*. 2010;41(7):e125-e131.
29. de Vasconcellos BT, Miranda-Júnior WG, Prioli R, Thompson J, Oda M. Surface roughness in ceramics with different finishing techniques using atomic force microscope and profilometer. *Oper Dent*. 2006;31(4):442-449. [CrossRef]
30. Flury S, Lussi A, Zimmerli B. Performance of different polishing techniques for direct CAD/CAM ceramic restorations. *Oper Dent*. 2010;35(4):470-481. [CrossRef]
31. Scotti N, Bregola A, Chiandussi G, Paolino D, Pasqualini D, Berutti E. Comparative evaluation of the enamel margins roughness obtained with different finishing devices. *Minerva Stomatol*. 2012;61(1-2):1-9.
32. Ahmad R, Morgano SM, Wu BM, Giordano RA. An evaluation of the effects of handpiece speed, abrasive characteristics, and polishing load on the flexural strength of polished ceramics. *J Prosthet Dent*. 2005;94(5):421-429. [CrossRef]
33. Steiner R, Beier US, Heiss-Kisielewsky I, Engelmeier R, Dumfahrt H, Dhima M. Adjusting dental ceramics: an in vitro evaluation of the ability of various ceramic polishing kits to mimic glazed dental ceramic surface. *J Prosthet Dent*. 2015;113(6):616-622. [CrossRef]