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Original research

Effects of polishing protocols on the surface roughness and color stability of polyetheretherketone (PEEK)

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Purpose
This study aimed to evaluate the effects of different polishing protocols on the surface properties and color stability of the polyetheretherketone (PEEK).

Materials and Methods
A total of 96 disc-shaped specimens were fabricated from PEEK material and divided into 6 different groups: control (CN), "Abraso-Starglanz" polishing paste (A), "Yildiz" polishing paste (Y), "Enhance" polishing system (EN), "Super snap" polishing kit (SS), and silicone polisher (SP). Surface roughness (R_a) were measured with a profilometer and the surface topography was examined under scanning electron microscope. Color differences were measured with a spectrophotometer according to the CIEDE2000 (ΔE_{00}) formulation before and after coffee immersion. Data were statistically analyzed with Kruskall–Wallis and Spearman's correlation analysis ($p<0.05$, $p<0.001$).

Results
A statistically significant difference was observed between the R_a measurements of the polishing protocols ($p<0.001$). R_a measurements except A, Y, and SS groups were found to be higher than the clinical acceptable threshold of surface roughness (0.20 µm). In ΔE_{00} measurements, statistically significant differences were observed between the CN and SP ($p=0.041$), EN ($p=0.001$), and A ($p=0.002$) polishing protocols. No correlation was found between R_a and color stability.

Conclusion
Only in the A, Y and SS polishing protocols, R_a measurements were not found to be risky in terms of acceptable threshold of surface roughness. Polishing protocols have also generally failed to maintain the color stability. Considering the surface roughness and color stability, the "Abraso-Starglanz" paste may be suitable method for PEEK material.

Keywords: *Surface roughness, color stability, polyetheretherketone, PEEK, CIEDE2000*

Introduction

Polyetheretherketone (PEEK) is a synthetic polymeric material that is available in tooth-colored forms for use in dentistry (1, 2). PEEK is biocompatible, has low specific weight, low allergy potential, and low water absorption properties. It also has superior chemical, thermal, and mechanical properties. As a result, PEEK material has started to be used in dentistry as an implant body and superstructure, fixed partial dentures, and infrastructure of removable prosthesis (2-10).

However, like all dental materials, the clinical success and longevity of this material, which is increasingly used as an alternative to traditional restorative materials, highly depend on some parameters (3, 4, 7, 8, 11, 12). One of these essential parameters is the quality of the material surface polishing. This is because the surface roughness of the dental material is a risk factor in the development of bacterial retention, caries, gingivitis,

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periodontitis, peri-implantitis, stomatitis, harmful abrasive effects on natural teeth or restoration, and other problems (1, 7, 8, 12-17). Previous studies have reported that the clinical acceptable threshold for the roughness of a prosthetic restoration surface is 0.2 µm (7, 8, 18). Therefore, it is especially necessary to apply the correct polishing procedures under appropriate conditions to increase the longevity of prosthetic restorations (1, 8).

The polishing quality of the surface can be affected by the material's hardness, wear resistance, and polishing protocols (7, 8, 12). There are many polishing materials and laboratory or chairside polishing protocols that can be used in dentistry (1, 7, 8). However, little is known in the literature about a user guide for these protocols, the effect of polishing on PEEK material surface roughness, and which protocols provide a more successful surface finish of the PEEK material (4, 7, 8, 12-14).

In addition to surface roughness, the color stability of the material is also crucial for the long-term success of the restoration. Many factors affect the color stability in restorative materials, such as the material type and composition, polymerization mode, fabrication process, aging of the material, prolonged exposure to coloring foods, smoking, and oral hygiene habits (3, 18, 19). It has been reported that the polishing quality of the material surface can also affect the color stability (7, 12, 18, 20). However, there is limited knowledge on the effect and long-term performance of polishing protocols and polishing materials on the color stability of PEEK materials (4, 7, 12, 18, 21).

Therefore, this study aimed to evaluate the surface roughness and color stability of PEEK material after applying different polishing protocols. The null hypothesis of the study was that different polishing protocols would not affect the surface roughness and color stability of the PEEK material.

Materials and Methods

Sample size estimation

In this *in vitro* study, the total specimen size was calculated using the G-POWER program with 0.4 effect size, 80% power, and 0.05 sampling error, based on the percentage of the measurement values for the methods to be studied. Based on the calculation, the number of specimens for the ANOVA test was determined by considering 6 independent groups.

Specimen characteristics

A total of 96 disc-shaped specimens of 3 mm thickness and 10 mm diameter were prepared from PEEK material using CAD/CAM production technology (Table 1). Information about the pre-treatment process and polishing protocols were summarized in Figure 1 and Table 2. All polishing materials were used according to the manufacturers' instructions and all polishing procedures were completed by the same researcher (S.C.S.).

Surface roughness

Surface roughness measurements were used to analyze the specimen surface quality of all groups after polishing protocols. In order to prevent any residue on the surface that may affect the roughness results after the polishing protocol, cleaning of the specimens with alcohol and distilled water was repeated (8). Measurements were made with a diamond-tipped contact profilometer (Mahr Perthometer

Table 1. *Information about the test material.*

Brand	Composition	Lot No.	Manufacturer
CopraPeek Light	Polyetheretherketone (≈ 80 %) Titanium dioxide (< 20%) Other additives (< 0.1%)	E10061	Whitepeaks Dental Solutions GmbH & Co. KG, Germany

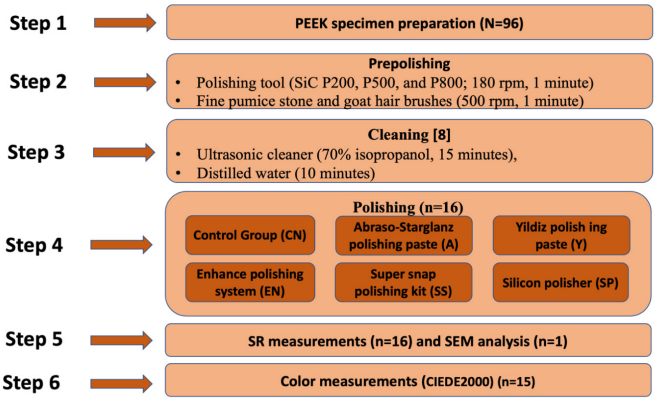

Figure 1. *Step-by-step the study design (SiC: silicon carbid, SR: surface roughness, SEM: scanning electron microscopy).*

Table 2. *Polishing protocols, products and application procedures*

Polishing Protocols	Products	Application Protocols*	Manufacturer
Laboratory	Abraso-Starglanz polishing paste **(A)**	1 minute at 3000 rpm with a polishing buff	bredent GmbH & Co KG, Germany
	Yildiz polishing paste **(Y)**	1 minute at 10 000 rpm with a polishing mop	Yildiz Cila Company, Turkey
	Renfert silicone polisher **(SP)**	1 minute at 12 000 rpm	Renfert GmbH, Germany
Chairside	Enhance Prisma® Gloss™ polishing system **(EN)**	1 minute at 10 000 rpm with polishing cubs and extra-fine composite polishing paste	Dentsply De Trey GmbH, Germany
	Super snap rainbow technique kit **(SS)**	30 second at 12 000 rpm with violet, green and pink discs, respectively	Shofu Dental GmbH, Germany

**Polishing process was repeated by renewing the polishing paste every 30 second. In addition, the buff, cubs, silicone polisher or disk used in the polishing procedure were changed in each specimen.*

M2; Mahr GmbH, Germany) applying a measuring force of 0.7 mN with a trace length of 6 mm. Surface roughness measurements were made at 3 different areas on each specimen by moving the diamond tip of the device along the specimen surface in parallel, and the specimen's average roughness (R_a) were calculated. After each measurement, the profilometer was calibrated with a special calibration block. R_a measurement results of the 5 polished groups were compared with the control group.

A random specimen was chosen from each of the control and polishing groups. The surface topography of these specimens was evaluated in the scanning electron microscope (SEM; Supra40VP, Zeiss, Germany). For topographic examination, specimens' surfaces were coated with 80% gold and 20% palladium using a sputtered device (Q150R ES, Quorum Technologies, UK) to make them conductive. The surfaces were then evaluated using the original ×300, ×600, ×1000, and ×2500 magnifications at 20 kV.

Color measurement

After the polishing protocols and surface roughness measurements were completed, the color parameters (L*, a*, b*) of all groups were measured with a digital spectrophotometer (Vita Easy Shade V, Vita Zahnfabrik, Germany) and recorded according to the Commission International de l'Eclairage (CIE) Lab 3D color system. Color measurements for each specimen were repeated on a white background at 3 different points in the center of the sample at a 90-degree angle to the specimen surface, and the measurement averages were recorded (L_0*, a_0*, b_0*). After each measurement, the device was calibrated.

Staining process

According to the manufacturer's instructions, the staining solution was prepared by dissolving 2 g of coffee (Nescafe Classic, Nestle, Sweden) in 200 mL of boiled distilled water. The specimens were embedded in the staining solution and stored in an incubator (EN055, Nüve, Turkey) at 37 °C for 30 days as static. In order to prevent the decrease in solution efficiency and to prevent coffee particles sedimentation, the staining solution was changed every 2 days (22). After the staining procedure, the specimens were washed with distilled water for 10 minutes and oil-free air-dried. After this procedure, the second color measurements of the specimens were repeated and recorded to compare with the first measurements (L_1*, a_1*, b_1*). All measurements were made by the same practitioner (S.C.S.).

The color change values of the specimens were evaluated with the current CIEDE2000 (ΔE_{00}) color difference formula (18, 23-25):

$$\Delta E_{00} = [(\Delta L'/K_L S_L)^2 + (\Delta C'/K_C S_C)^2 + (\Delta H'/K_H S_H)^2 + RT(\Delta C'/K_C S_C)(\Delta H'/K_H S_H)]^{1/2}$$

In the formula above, ΔL' represents the difference in lightness, ΔC' represents the difference in chroma, and ΔH' represents the differences in hue. R_T is a correction factor based on chroma and hue differences. The S_L, S_C, S_H concepts describe average factors for lightness, chroma, and hue. K_L, K_C, and K_H are weighed parametric factors expressing the experimental conditions (2, 3, 26). In this study, K_L was set to 2, and K_C and K_H were both set to 1 (27-30).

According to the latest guidance on color measurements, color stability after aging and staining should be assessed based on 50:50% acceptability (ΔE_{00}=1.8) and 50:50% perceptibility (ΔE_{00}=0.8) thresholds (27, 31, 32). In this study, color stability was evaluated with these threshold values. In addition, ΔE_L, ΔE_C, and ΔE_H intermediate components were also calculated and compared.

Statistical analysis

The NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. The normality distribution of the data was evaluated by the Kolmogorov–Smirnov test. The Kruskall–Wallis test was used to analyze the differences between surface roughness and color stability results according to the polishing protocols. The Mann–Whitney U test was used for pairwise comparisons of groups with significant differences. Spearman's correlation analysis was used to evaluate the correlation between surface roughness and color stability. Significance was evaluated as $p < 0.05$ and $p < 0.001$.

Results

The highest R_a results were found in the CN group, followed by the SP, EN, Y, SS, and A polishing groups (Table 3).

Table 3. *Surface roughness measurements and color stability results of PEEK material after laboratory and chairside polishing protocols.*

Polishing Protocols (n=15)	Surface Roughness (R_a)		p*	ΔE_{00}		p*
	Mean ± SD	Min-Max (Median)		Mean ± SD	Min-Max (Median)	
CN	0.49 ± 0.1	0.37-0.77 (0.47)[a]		4.38 ± 2.03	0.48-7.50 (4.71)[a]	
A	0.11 ± 0.03	0.06-0.21 (0.11)[b]		1.85 ± 1.82	0.21-5.97 (1.3)[b]	
Y	0.16 ± 0.05	0.08-0.25 (0.15)[c]		4.07 ± 2.10	0.76-8.09 (4.46)[a,c]	
SP	0.45 ± 0.08	0.35-0.73 (0.42)[a]	***0.001****	2.87 ± 2.32	0.34-9.11 (2.27)[b,c]	***0.001****
EN	0.29 ± 0.03	0.25-0.38 (0.29)[d]		1.54 ± 1.52	0.28-6.23 (1.20)[b]	
SS	0.12 ± 0.02	0.09-0.18 (0.12)[b,c]		3.63 ± 2.19	0.78-8.4 (3.73)[a,c]	

**Kruskall–Wallis test and Mann–WhitneyU test: $p < 0.05$ and $p < 0.001$. There was no statistically significant difference between the polishing protocols represented by the same letters, but a statistically significant difference was found between the groups with different lettering. SD: Standard deviation.*

A statistically significant difference between CN group and other groups was observed according the R_a measurements (p=0.001; p < 0.001). R_a values for the CN, SP, and EN groups were found to be higher than the acceptable surface roughness threshold level (0.20 µm) for prosthetic restorations. While there was no significant difference between the R_a measurements of the CN and SP groups (p = 0.158), the R_a measurements of all other groups were significantly lower than the CN group (p < 0.001). The SP polishing protocol, which is one of the laboratory-polishing protocol, showed higher R_a values than the A and Y laboratory-polishing protocols (p < 0.001). Of the chairside-polishing protocols, the EN polishing protocol was found to exhibit higher R_a values than the SS protocol (p < 0.001). However, Ra values of the SS polishing protocol were not statistically different from the laboratory-polishing protocols A (p=0.067) and Y (p=0.124) (Table 3).

Images of SEM evaluations for all polishing protocols are presented in Figure 2. According to these images, deep roughness lines were observed along the entire surface in the CN group. Although the surface was smoother in the SP and EN polishing groups than in the CN group, deep roughness areas were found in some parts of the specimens' surfaces, while areas of superficial and fine linear roughness were also detected, especially in groups A and SS.

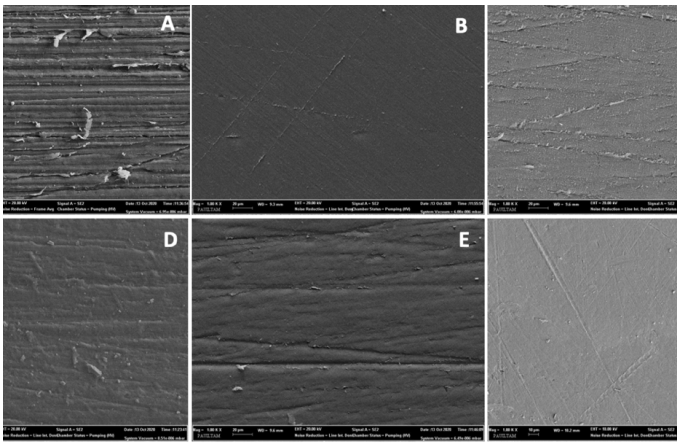

Figure 2. *SEM images (x1000 magnification) of all protocols. A, Control (Group CN). B, Abraso-Starglanz polishing paste (Group A). C, Yildiz polishing paste (Group Y). D, Renfert silicone polisher (Group SP). E, Enhance Prisma® Gloss™ polishing system (Group EN). F, Super snap rainbow technique kit (Group SS).*

The ΔE_{00} measurements of the polishing protocols were also significantly different (p=0.001; p < 0.001). The highest ΔE_{00} measurements were obtained for the CN group, and the lowest for the EN polishing group (Table 3). In ΔE_{00} measurements, statistically significant differences were observed especially between the CN group and SP (p=0.041, p < 0.05), EN (p=0.001, p < 0.001), and A (p=0.002, p < 0.001) polishing protocols. ΔE_{00} measurements for group A was statistically lower than the Y (p=0.007) and SS (p=0.001) groups. However, no significant difference was observed between the Y and SS groups (p > 0.05) (Table 3).

In addition, ΔE_{00} measurements of the A and EN polishing groups were found to be below the acceptability threshold value (ΔE_{00}=1.8). The values obtained for all other polishing protocols were above the threshold limit. In terms of perceptibility, the ΔE_{00} measurements of all groups were found above the threshold limit (ΔE_{00}=0.8) (Table 3). On the other hand, when the relationship between surface roughness and color stability measurements was evaluated, no significant correlation was found (r=0.144, p=0.176).

Table 4 summarizes $\Delta E_L'$ (lightness), $\Delta E_C'$ (chroma) and $\Delta E_H'$ (hue) measurement data of PEEK material after all polishing protocols. According to the statistical analyses, $\Delta E_L'$, $\Delta E_C'$, and $\Delta E_H'$ measurements for all polishing protocols compared were significantly different from each other (p < 0.001). In terms of $\Delta E_L'$ and $\Delta E_C'$, a statistically significant difference was found between the CN group and the A, SP, and EN polishing groups (p < 0.001), while this difference in terms of $\Delta E_H'$ was detected between the CN group and the A, SP, EN, and SS polishing groups (p < 0.001). A detailed comparison of the statistical differences of all polishing protocols is shown in Table 4.

Table 4. *$\Delta E_L'$, $\Delta E_C'$ and $\Delta E_H'$ measurements of PEEK material after all polishing protocols.*

Polishing Protocol (n=15)	$\Delta E_L'$		p	$\Delta E_C'$		p	$\Delta E_H'$		p
	Mean ± SD	Min-Max (Median)		Mean ± SD	Min-Max (Median)		Mean ± SD	Min-Max (Median)	
CN	-2.9 ± 1.64	-5.58 ± -0.13 (-3.06)^{a}		3.09 ± 1.36	0.25 ± 4.72 (3.38)^{a}		-0.98 ± 0.4	-1.78 ± -0.38 (-0.93)^{a}	
A	-1.1 ± 1.33	-4.17 ± 0.13 (-0.7)^{b,c}		1.32 ± 1.4	-0.18 ± 4.09 (1)^{b,c,d}		-0.37 ± 0.3	-1.18 ± -0.1 (-0.31)^{b}	
Y	-2.62 ± 1.61	-5.77 ± -0.35 (-2.55)^{a,d}		2.93 ± 1.33	0.61 ± 5.2 (3.01)^{a,e}		-0.94 ± 0.54	-2.28 ± -0.29 (-0.88)^{a}	
SP	-1.69 ± 1.81	-6.81 ± 0.23 (-1.26)^{b,d}	***0.001***	2.11 ± 1.57	-0.14 ± 5.68 (1.82)^{c,d,e}	***0.001***	-0.61 ± 0.46	-2.05 ± -0.16 (-0.5)^{c}	***0.001***
EN	-0.76 ± 1.18	-4.43 ± 0.43 (-0.54)^{b}		1.03 ± 1.21	-0.39 ± 4.21 (0.98)^{b}		-0.42 ± 0.24	-1.21 ± -0.15 (-0.4)^{b}	
SS	-2.02 ± 1.94	-6.3 ± 1.03 (-2.21)^{a,c,d}		2.43 ± 1.96	-1.22 ± 5.26 (2.98)^{a,d}		-0.57 ± 0.49	-1.77 ± 0.04 (-0.43)^{b,c}	

Kruskall–Wallis test and Mann–Whitney U test: p < 0.05 and p < 0.001. There was no statistically significant difference between the polishing protocols represented by the same letters, but a statistically significant difference was found between the groups with different lettering. SD: Standard deviation.

Discussion

This study initially hypothesized that different polishing protocols would not affect the surface roughness and color stability of PEEK material, but the study results rejected this null hypothesis.

There are only a few studies available that examine the surface properties of PEEK material and how these properties can be enhanced (4, 7, 13, 14). Surface properties and roughness values of restorative materials play a significant role in adhesion, a stage of plaque formation. It is clinically crucial for prosthetic restorative materials to have surface properties that prevent plaque accumulation and adhesion, as well as reduce the risk of caries in surrounding teeth (7).

To ensure that the prosthetic restorative materials exhibit ideal surface properties, it is crucial to select the most effective polishing protocol after performing occlusal adjustments during intraoral trial sessions and production stages of the restorations. The most important factor in choosing a polishing protocol is to achieve a shiny and smooth restoration surface with low Ra values, which prevents bacterial adhesion (7, 13, 14, 16). In the current study, Ra values ranged from 0.06 µm to 0.77 µm. SEM images of the groups with the highest and lowest Ra measurements matched the roughness data. Moreover, only surface roughness measurements taken from two laboratory-polishing protocols (A and Y groups) and one chairside-polishing protocol (SS group) were below the critical surface roughness threshold value for prosthetic restorations (7, 8, 18).

Heimer *et al.* (7) and Hahnel *et al.* (17) consistently compared laboratory and chairside polishing protocols using similar polishing materials and protocols. However, differences in Ra measurements were found between the studies, which may be attributed to changes in application time and speed (7, 17). Furthermore, variations in hardness of the tested PEEK materials may also account for differences in Ra measurements between studies. According to Heimer *et al.* (7), materials with higher hardness may achieve lower Ra values after polishing than softer materials. The PEEK material utilized in the present study contains approximately 20% titanium content and is considerably harder than materials utilized in similar studies. Therefore, it is plausible to obtain lower roughness values in this study, even with similar polishing protocols (8).

The most successful Ra measurements were observed in the A group among the methods tested in this study. This result may be attributed to the use of a liquid-based polishing paste, resulting in finer abrasion and a brighter, slightly reflective surface. The polishing material used in the A polishing protocol may have also contributed to the brighter and slightly reflective surface of the specimen, leading to more successful results in terms of surface roughness (1, 7).

It has been reported that 3-body abrasion techniques, which involve polishing pastes containing aluminum oxide or diamond particles, result in lower surface roughness than 2-body abrasion techniques made by grinding with burs, bonded adhesives, or coated abrasives. Therefore, it is possible that the A polishing protocol, which is a 3-body polishing technique, provided more successful Ra measurements than other polishing protocols and the control group (7, 33). On the other hand, both the EN polishing group and the A polishing group utilized 3-body polishing techniques and liquid-based polishing pastes for similar purposes. However, despite applying the polishing paste at a higher rpm in the EN polishing group, Ra values was higher than those of the A polishing group and the roughness threshold value specified for prosthetic restorations. This discrepancy in Ra values may be due to differences in the grain sizes of the abrasive materials used in these protocols (13).

In this study, coffee was used as the staining agent due to its high staining potential, as reported in previous studies (2, 34, 35). Immersion time is another important factor affecting color stability, and studies have shown that the most significant color change occurs after 30 days (36, 37). To simulate clinical aging, the specimens in this study were immersed for 30 days, which is equivalent to 2.5 years of in vivo use (35, 36, 38). Other factors, such as surface roughness and surface-free energy, have also been reported to affect color stability (3, 20, 37), likely due to the coloring solution being in contact with a larger surface area (3, 20). However, in the present study, no significant correlation was found between surface roughness measurements and color stability ($p > 0.05$). When the color stability of the groups with the smoothest surfaces (A, Y, and SS groups) was examined, the A group showed an acceptable color change ($\Delta E00=1.3$), while the other groups showed higher color changes ($\Delta E00>1.8$). The EN group, which had a surface roughness value above the threshold value (0.29 µm), exhibited the lowest acceptable color change value ($\Delta E00=1.2$) among all groups.

he discoloration of restoration surfaces is affected by electrostatic forces (van der Waals forces), hydrophobic properties, and the absorption or adsorption capacity of the materials (3). In the present study, the main reason for the color changes may be attributed to the PEEK material's lower absorption or adsorption capacity of the coffee staining agent, rather than the surface roughness (34, 35, 37). The positive color stability results achieved in the A and EN polishing procedures may be due to the lower absorption or adsorption possibility of the coloring agent, which is relevant to the surface properties obtained. More detailed evaluations are required in current studies (1, 3, 7).

Few studies in the literature compare the color stability results of PEEK material. The ability to compare the study outcomes has been negatively affected by the fact that different color formulas have been evaluated, different polishing protocols have been used, and there are differences in staining solution and immersion time (2, 3). In most of the studies, the ΔEab formula was used to estimate the color differences, but a newer formula, $\Delta E00$, has been proposed to calculate color differences. Some studies have found a high correlation between the color change data calculated with both formulas. This up-to-date formula has started to be recommended, especially for materials with high chroma, because of its success in detecting small color differences and the visual color difference perception (2, 25, 28, 29, 39). Nevertheless, very few studies have used this new formula for PEEK material or have investigated perceptibility-acceptability threshold values (2, 3, 18). The different formulations used in previous PEEK material studies and the different references used as the basis for the perceptibility-acceptability threshold values mean that the current study results are not comparable

with the results of similar studies. In addition, the difference in the data set values of the "K" parameter in the ΔE00 formula, which affects the color change results, negatively affected the comparability of the studies (2, 18, 30). The K parameters in the present study were selected as 2, 1, and 1 by using data from the literature (27, 28). However, studies in which this value was determined include the results from porcelain materials or human teeth structures (27-29). Research on acceptability thresholds, especially for polymer-based materials, is insufficient and much needed (2).

In this study, only one staining agent was tested to evaluate its effectiveness on color stability. To improve this one, various staining agents, including distilled water, coffee, fruit juice, and their combinations, could be tested. However, it is important to note that other factors, such as the nutritional habits, oral hygiene practices, smoking status, and salivary microflora of patients, may also influence both surface roughness and color stability. Hence, more in vivo and in vitro studies are required to examine the long-term surface and optical properties of PEEK materials and assess the efficacy of polishing protocols on these properties as well as bacterial adhesion.

Conclusion

Many of the laboratory and chairside polishing protocols exhibited risky surface properties for clinical acceptable threshold for the roughness of a prosthetic restoration. The color stability of PEEK material was found to be insufficient in most of the polishing protocols groups. Considering the surface roughness and color change values, the laboratory-based "Abraso-Starglanz" polishing paste protocol may be suitable method for PEEK material.

Türkçe özet: *Parlatma protokollerinin polietereterketonun (PEEK) yüzey pürüzlülüğü ve renk stabilitesi üzerindeki etkisi. Amaç: Bu çalışmada farklı polisaj protokollerinin polietereterketonun (PEEK) yüzey özellikleri ve renk stabilitesi üzerindeki etkilerinin değerlendirilmesi amaçlanmıştır. Gereç ve yöntem: PEEK malzemesinden toplam 96 adet disk şeklinde numune üretildi ve kontrol (CN), "Abraso-Starglanz" cila pastası (A), "Yıldız" cila pastası (Y), "Enhance" polisaj sistemi (EN), "Super snap" polisaj kiti (SS) ve silikon parlatıcı (SP) uygulamalarını içerecek şekilde 6 farklı gruba ayrıldı. Yüzey pürüzlülüğü (Ra) profilometre yardımıyla ölçüldü ve yüzey topografisi taramalı elektron mikroskobu altında incelendi. Renk farklılıkları, örnekler kahveye daldırmadan önce ve sonra CIEDE2000 (ΔE00) formülasyonuna göre spektrofotometre aracılığıyla hesaplandı. Elde edilen veriler Kruskall-Wallis ve Spearman's korelasyon analizi ile istatistiksel olarak analiz edildi ($p < 0.05$, $p < 0.001$). Bulgular: Parlatma protokolleri sonrasında örneklerin Ra ölçümleri arasında istatistiksel olarak anlamlı bir fark gözlemlendi ($p < 0.001$). A, Y ve SS grupları dışındaki Ra ölçümleri, klinik olarak kabul edilebilir yüzey pürüzlülüğü eşiğinden (0.20 µm) daha yüksek değerlerde bulundu. ΔE00 ölçümlerinde CN ve SP ($p=0.041$), EN ($p=0.001$) ve A ($p=0.002$) polisaj protokolleri arasında istatistiksel olarak anlamlı farklılıklar gözlendi. Ra ile renk stabilitesi arasında ise bir korelasyon saptanmadı. Sonuç: A, Y ve SS polisaj protokollerinde elde edilen Ra değerlerinin kabul edilebilir yüzey pürüzlülüğü eşiği açısından riskli olmadığı tespit edilmiştir. Test edilen polisaj protokolleri çoğunlukla renk stabilitesini korumakta başarısız olmuştur. Yüzey pürüzlülüğü ve renk stabilitesi göz önüne alındığında, "Abraso-Starglanz" polisaj pastasının PEEK malzemesi ile kullanıma daha uygun bir yöntem olabileceği tespit edilmiştir. Anahtar Kelimeler: Yüzey pürüzlülüğü, renk stabilitesi, polietereterketon, PEEK, CIEDE2000*

Ethics Committee Approval: The *in vitro* study was approved by the Medical Ethics Committee of Pamukkale University (Approval number: 60116787-020/59518).

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References

1. Sturz CRC, Faber FJ, Scheer M, Rothamel D, Neugebauer J. Effects of various chair-side surface treatment methods on dental restorative materials with respect to contact angles and surface roughness. Dent Mater J 2015;34:796-813. [CrossRef]
2. Polychronakis N, Lagouvardos P, Polyzois G, Sykaras N, Zoidis P. Color changes of polyetheretherketone (PEEK) and polyoxymethelene (POM) denture resins on single and combined staining/cleansing action by CIELab and CIEDE2000 formulas. Prosthodont Res 2020;64:159-66. [CrossRef]
3. Heimer S, Schmidlin PR, Stawarczyk B. Discoloration of PMMA, composite, and PEEK. Clin Oral Investig 2017;21:1191-1200. [CrossRef]
4. Liebermann A, Wimmer T, Schmidlin PR, Scherer H, Löffler P, Malgortata R, Stawarczyk B. Physicomechanical characterization of polyetheretherketone and current esthetic dental CAD/CAM polymers after aging in different storage media. J Prosthet Dent 2016;115:321-8. [CrossRef]
5. Kurtz SM, Devine JN. PEEK biomaterials in trauma, orthopedic, and spinal implants. Biomaterials 2007;28:4845-69. [CrossRef]
6. Fuhrmann G, Steiner M, Freitag-Wolf S, Kern M. Resin bonding to three types of polyaryletherketones (PAEKs)-Durability and influence of surface conditioning. Dent Mater 2014;30:357-63. [CrossRef]
7. Heimer S, Schmidlin PR, Roos M, Stawarczyk B. Surface properties of polyetheretherketone after different laboratory and chairside polishing protocols. J Prosthet Dent 2017;117:419-25. [CrossRef]
8. Kurahashi K, Matsuda T, Ishida Y, Ichikawa T. Effect of polishing protocols on the surface roughness of polyetheretherketone. J Oral Sci 2020;62:40-2. [CrossRef]
9. Panayotov IV, Orti V, Cuisinier F, Yachouh J. Polyetheretherketone (PEEK) for medical applications. J Mater Sci Mater Med 2016;27:118. [CrossRef]
10. Harb IE, Abdel-Khalek EA, Hegazy SA. CAD/CAM constructed Poly(etheretherketone) (PEEK) framework of Kennedy Class I removable partial denture: A clinical report. J Prosthodont 2019;28:595-8. [CrossRef]
11. Najeeb S, Zafar MS, Khurshid Z, Siddiqui F. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. J Prosthodont Res 2016;60:12-9. [CrossRef]
12. Jefferies SR. Abrasive finishing and polishing in restorative dentistry: A state-of-the-art review. Dent Clin North Am 2007;51:379-97. [CrossRef]
13. Schönhoff LM, Mayinger F, Eichberger M, Lösch A, Reznikova E, Stawarczyk B. Three-dimensionally printed and milled polyphenylene sulfone materials in dentistry: Tensile bond strength to veneering composite resin and surface properties

after different pretreatments. J Prosthet Dent 2021. Epub ahead of print. Available from: https://www.thejpd.org/article/S0022-3913(21)00027-5/pdf
14. Batak B, Çakmak G, Johnston WM, Yilmaz B. Surface roughness of high-performance polymers used for fixed implant-supported prostheses. J Prosthet Dent 2021;126: 254.e1-254.e6. [CrossRef]
15. Teughels W, Van Assche N, Sliepen I, Quirynen M. Effect of material characteristics and/or surface topography on biofilm development. Clin Oral Implants Res 2006;17:68-81. [CrossRef]
16. Auschill TM, Arweiler NB, Brecx M, Reich E, Sculean A, Netuschil L. The effect of dental restorative materials on dental biofilm. Eur J Oral Sci 2002;110:48-53. [CrossRef]
17. Hahnel S, Wieser A, Lang R, Rosentritt M. Biofilm formation on the surface of modern implant abutment materials. Clin Oral Implants Res 2015;26:1297-1301. [CrossRef]
18. Köroğlu A, Sahin O, Dede DÖ, Yilmaz B. Effect of different surface treatment methods on the surface roughness and color stability of interim prosthodontic materials. J Prosthet Dent 2016;115:447-55. [CrossRef]
19. Zoidis P, Polychronakis N, Lagouvardos P, Polyzois G, Ngo HC. Evaluation of a realistic cleansing protocol for preventing discoloration of denture resins. J Prosthodont 2019;28:89-95. [CrossRef]
20. Gönülol N, Yilmaz F. The effects of finishing and polishing techniques on surface roughness and color stability of nanocomposites. J Dent 2012;40:64-70. [CrossRef]
21. Stawarczyk B, Schmid P, Roos M, Eichberger M, Schmidlin PR. Spectrophotometric evaluation of polyetheretherketone (PEEK) as a core material and a comparison with gold standard core materials. Materials 2016;9:491. [CrossRef]
22. Samra APB, Pereira SK, Delgado LC, Borges CP. Color stability evaluation of aesthetic restorative materials. Braz Oral Res 2008;22:205-10. [CrossRef]
23. Sharma G, Wu W, Dalal EN. The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. Color Res Appl 2005;30:21-30. [CrossRef]
24. Lee YK. Comparison of CIELAB ΔE* and CIEDE2000 color-differences after polymerization and thermocycling of resin composites. Dent Mater 2005;21:678-82. [CrossRef]
25. Luo MR, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. Color Res Appl 2001;26:340-50. [CrossRef]
26. Mekkawy M, Hussein L, Elsharawy HL. Comparative study of surface roughness between polyamide, thermoplastic polymethyl methacrylate and acetal resins flexible denture base materials before and after polishing. Life Sci 2015;12:90-5.
27. Pérez MM, Pecho OE, Ghinea R, Pulgar R, Bona AD. Recent advances in color and whiteness evaluations in dentistry. Curr Dent 2018;20:23-9. [CrossRef]
28. Perez MM, Ghinea R, Herrera LJ, Ionescu AM, Pomares H, Pulgar R, Paravina RD. Dental ceramics: A CIEDE2000 acceptability thresholds for lightness, chroma and hue differences. J Dent 2011;39:37-44. [CrossRef]
29. Pecho OE, Ghinea R, Alessandretii R, Pérez MM, Bona AD. Visual and instrumental shade matching using CIELAB and CIEDE2000 color difference formulas. Dent Mater 2016;32:82-92. [CrossRef]
30. Mangine H, Jakes K, Noel C. A preliminary comparison of CIE color differences to textile color acceptability using average observers. Color Res Appl 2005;30:288-94. [CrossRef]
31. International Organization for Standardization. ISO/EN 28642:2016 Dentistry-Guidance on color measurement.
32. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, et al. Color difference thresholds in dentistry. J Esthet Restor Dent 2015;27:1-9. [CrossRef]
33. Hondrum SO, Jr. Fernández R. Contouring, finishing, and polishing class 5 restorative materials. Oper Dent 1997;22:30-6.
34. Bayindir F, Kürklü D, Yanikoğlu ND. The effect of staining solutions on the color stability of provisional prosthodontic materials. J Dent 2012;40:41-6. [CrossRef]
35. 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;94:118-24. [CrossRef]
36. Ahmed SS, Abdelhalim EF, Amgad SW. Color stability of two machinable restorative materials. EDJ 2019;65:1-11.
37. Yannikakis SA, Zissis AJ, Polyzois GL, Caroni C. Color stability of provisional resin restorative materials. J Prosthet Dent 1998;80:533-9. [CrossRef]
38. Ali YD, Ahmed SEK, Mona MG, Maha AA. In vitro comparative study of Lava Ultimate CAD/CAM restorative system in comparison to IPS e-max press. Alex Dent J 2016;41:156-62. [CrossRef]
39. Melgosa M, Huertas R, Berns RS. Performance of recent advanced color-difference formulas using the standardized residual sum of squares index. J Opt Soc Am A 2008;25:1828. [CrossRef]