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Araştırma Makalesi/ Research Article

Sigaranın Farklı CAD/CAM Bloklarının Renk Değişimi Üzerindeki Etkisinin İncelenmesi

Sigaranın Dental Materyallere Etkisi

Examination of The Effect of Smoking on The Discoloration of Different CAD/CAM Blocks

Effect of Smoking on Dental Materials

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Amaç: Dijital diş hekimliği indirekt restorasyonlarda kullanılan dental materyallerde kaçınılmaz bir değişime yol açmıştır. Literatürde bu malzemelerin renklenmeleri ile ilgili bilgi eksikliği bulunmaktadır. Farklı ajanlara maruz kalma, materyallerin lekelenmesine yol açarak restoratif materyaller arasında estetik değişkenliğe neden olabilir. Sigara dumanının günümüzde yaygın olarak kullanılan dental materyallerde renk bozulmasına neden olduğu gösterilmiştir. Bu çalışmanın amacı sigara dumanına ve fırçalamaya maruz kalan 3 dental CAD/CAM materyalinin renk stabilitesini değerlendirmektir. **Gereç ve Yöntem:** Farklı yüzey işlemlerinden (sırlı, cilalı) 1 mm kalınlığında 20 adet olmak üzere toplam 100 adet disk hazırlandı. Temel renk ölçümü, bir kolorometre kullanılarak yapıldı. Örnekler iki gruba ayrıldı: kontrol ve deney. Deney numuneleri, sigara içen bir kişinin sigara dumanına maruz kalmasına benzer şekilde, sigara içmeyi simüle eden koşullara tabi tutuldu. Kontrol örnekleri yapay tükürükte saklandı. Maruziyetten sonra, renk ölçümü yapıldı ve her işlem grubunun renk farkını kantitatif olarak analiz etmek için L*a*b değerleri kullanılarak müdahaleden önce ve sonra renk değişimi (ΔE) hesaplandı. İstatistiksel analiz için iki yönlü ANOVA ve Tamhane post hoc testleri kullanıldı ($\alpha = 0.05$). **Bulgular:** Sigara dumanına maruz kalan tüm numunelerde, yaşlanmaya tabi tutulan numunelere göre daha yüksek bir ortalama renk değişimi meydana geldi. Sigara dumanına maruz kalan tüm test materyallerinde klinik olarak kabul edilen değerin ($\Delta E > 3.3$) üzerinde renk değişimi bulundu. Sigara dumanına maruz kaldıktan sonra, bir diş fırçası ile fırçalanan tüm test edilmiş restorasyon materyallerinde renkleşmede azalma görüldü. **Sonuç:** Sigara alışkanlığına daha az duyarlı renk değişikliği ile yeni restoratif materyaller ve temizleme teknikleri geliştirilmelidir.

Anahtar Kelimeler: Sigara, Tütün, Diş Protez Renkleşmesi, Biyomedical ve Dental Materyaller

Aim: Digital dentistry has led to an inevitable change in dental materials used for indirect restorations. There is a lack of information in the literature about the discoloration of these materials. Exposure to different agents can lead to staining of the materials, resulting in esthetic variability between restorative materials. It has been shown that cigarette smoke causes discoloration of dental materials that are widely used today. To evaluate the color stability of 3 dental CAD/CAM materials subjected to cigarette smoke and brushing. **Material and Method:** A total of 100 discs, 20 for each, with 1 mm thick material, were prepared from different surface treatments (glazed, polished). Baseline color measurement was made using a colorometer. The samples were divided into two groups: control and experimental. Experimental specimens were subjected to conditions simulating smoking, similar to a smoker being exposed. Control samples were stored in artificial saliva. After exposure, color measurement was performed, and color change (ΔE) was calculated before and after intervention using L*a*b values to analyze the color difference of each treatment group quantitatively. Two-way ANOVA and Tamhane post hoc tests were used for statistical analysis ($\alpha = 0.05$). **Result:** A higher mean color change occurred in all samples exposed to cigarette smoke than in the corresponding samples subjected to aging. All test materials exposed to cigarette smoke had discoloration above the clinically accepted value ($\Delta E > 3.3$). After exposure to cigarette smoke, all tested restoration materials brushed with a toothbrush show a reduction in staining. **Conclusion:** New restorative materials and cleaning techniques need to be developed with less sensitive discoloration to the smoking habit.

Keywords: Smoking, Tobacco, Dental Prosthesis Coloring, Biomedical and Dental Materials

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INTRODUCTION

With the development of CAD/CAM (computer-aided design and manufacturing) systems and increased aesthetic and functional expectations, manufacturers have started researching and producing materials with different physical and chemical properties. The CAD/CAM materials used also vary according to the patient's expectations, the type of restoration, and its position in the mouth. Materials used with the CAD/CAM system; feldspathic, leucite reinforced glass, lithium disilicate reinforced glass, oxide sintered, zirconium oxide, hybrid, and glass ceramics reinforced with lithium disilicate and zirconia particles, composites, metals, and polymers (Fassbinder DJ, 2018).

The materials used with CAD/CAM systems affect clinical success. Since the materials consisting of prefabricated blocks and discs can be polymerized under optimum conditions, porosity formation can be prevented (Gougaloff & Stalley, 2010); homogeneous and standard quality restorations can be produced. There is a possibility of porosity in conventionally prepared restorations (Giordano, 2006).

Today, Lithium Disilicate glass-ceramic has become one of the most common materials used for indirect restorations in dentistry (Wang, Takahashi, & Iwasaki, 2013). Lithium dioxide, potassium oxide, phosphorus oxide, alumina, quartz, and trace minerals form the lithium disilicate glass-ceramic (Li2Si2O) structure. These ceramic restorations have high durability, aesthetics, biocompatibility, excellent wear properties, and the ability to adhere to the dentin and enamel structure after etching. First introduced as Ivoclar Vivadent's IPS Empress, this material can be pressed with the lost wax to produce full-contour ceramic restorations and lithium disilicate copings for porcelain layering (Guazzato, Albakry, Ringer, & Swain, 2004).

With CAD/CAM technology, IPS e.max was launched in prefabricated blocks for milling. Due to the increased chair-side and restoration design and milling speed, this restoration fabrication method has become the most common use of lithium disilicates in dentistry. After milling, firing, and glazing the lithium disilicate, the restoration is ready for clinical placement. The pre-and post-cementation adjustment can be completed with high-and low-speed handpieces with polishing burs. Polishing can be done according to the manufacturer's recommended instructions (Documentation, 2015).

During the firing and sintering processes, yttria oxide is added to stabilize the crystal structure of the zirconia (Conrad, Seong, & Pesun, 2007). Zirconia is one of the most robust indirect restoration materials available today (Liu, 2005). With CAD/CAM technology, restorations of prefabricated zirconia blocks are used by milling in the office or dental laboratories (Guess, Att, & Strub, 2012).

Restorations can be stained and polished from the milling and sintering processes to provide a final glossy esthetic appearance. The zirconia restoration can be minimally adjusted and polished for the desired final contour and occlusion, similar to other ceramic restorations (Stephen F. Rosenstiel, Martin F. Land, 2015). With computer-aided technology, yttria-stabilized zirconia (Zr2O2) has gained popularity. The crystal lattice structure of zirconia provides high strength combined with a glass-like aesthetic appearance (Guess et al., 2012).

Polyetheretherketone (PEEK) polymer is used in many areas, including infrastructure material in fixed and removable prostheses, temporary abutments, healing caps, and dental implants. PEEK is a relatively new material in dentistry compared to composite, ceramic, or zirconia (Seferli, 2020).

In terms of color stability and mechanical properties, the performance of polymeric fixed prostheses produced with CAD/CAM was compared with glass ceramics, and it was reported that polymers showed similar or better results than glass ceramics. PEEK, industrially; It can be produced in disc and block, pressed pellet, and granular form for CAD/CAM. However, granule and pellet form required heat pressing or melting. Studies on the performance of three-member fixed prostheses made of PEEK material have reported that materials produced in pellet form increase the stability and reliability of restorations. In addition, those produced in pellet form show lower plastic deformation and higher fracture toughness than fixed prostheses pressed from granular form (Wimmer, Huffmann, Eichberger, Schmidlin, & Stawarczyk, 2016).

In addition, using abrasive powders and manual cleaning tools over time causes damage to the surfaces of natural teeth and restorations (Khalefa, Finke, & Jost-Brinkmann, 2013). In this context, applicability, time requirements, and the possibility of damage to the placed restoration materials using different cleaning methods are essential parameters that should be carefully evaluated. However, there are currently no studies evaluating the cleaning protocols of lithium disilicate, zirconia, and PEEK materials and the rate of discoloration or cleaning due to smoking. This study compares the discoloration of the current restorative materials due to smoking.

MATERIAL AND METHOD

Of the CAD/CAM restorative materials, lithium disilicate CAD (IPS e.max CAD; Ivoclar Vivadent AG, Liechtenstein), PEEK (JUVORA™ PEEK; Straumann AG, Basel, Switzerland) and zirconia (Wieland Zenostar; Wieland Dental+Technik GmbH & Co. KG, Pforzheim, Germany) was used in sample preparation. 40 e.max CAD, 40 zirconia, and 20 PEEK specimens were prepared using a precision cutting device (IsoMet 1000; Buehler, Illinois, ITW, US) from raw restorative discs and blocks (Figure 2a). Each disc was cut underwater at 1 mm thickness at 200 rpm, and surface irregularities were eliminated underwater with fine sandpaper.

The thickness of the prepared discs (1±0.1) was measured with a digital caliper. After this preparation, e.max CAD samples in the blue phase were cleaned with steam and dried with a paper towel. A thin layer of glaze (IPS e.max CAD Crystall/Glaze; Ivoclar Vivadent AG, Liechtenstein) (2 brush strokes) was applied to one side of each e.max CAD specimen., and firing was performed in an Ivoclar Vivadent Programat CS2 furnace following the manufacturer's instructions to crystallize E.max CAD samples. According to the manufacturer's recommendations, green phase zirconia samples were sintered and glazed. Treated surfaces were observed with SEM microscope

(Phenom G2, The Netherlands) and photographed at 100x (Figure 3). The experimental workflow is described in Figure 1.

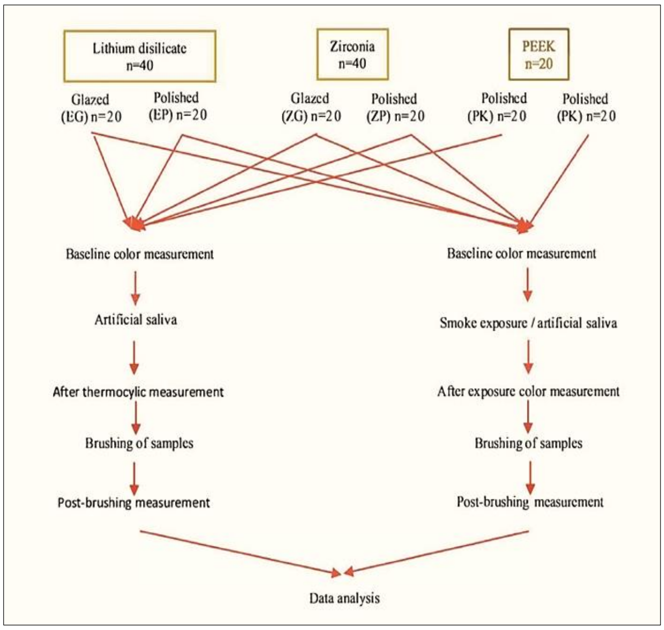

Figure 1: Study Design

Sample Testing and Color Measurement

Base color values were measured against CIELAB (the universally accepted colorimetric reference system for. quantifying and communicating color) values with a precision colorimeter (3nh NR145, Shenzhen Threenh Technology, Shenzhen, China) (Figure 2b). This chamber was constructed according to the specifications outlined in a previously published study by Alandia-Roman, and the samples were similarly exposed to cigarette smoke (Krishna, Kumar, & Savadi, 2009). A device was developed using a glass tube with support at one end for the cigarette to fit inside and a negative pressure induction system at the other end to absorb the smoke (Figure 2c). The cigarette releases smoke into the tube, thus creating the conditions of the smoker's oral cavity in vitro, impregnating the restorative materials with the substances contained in the smoke. The sample was placed in a chamber using a support matrix to allow the samples to remain vertical so that their surfaces were evenly exposed to cigarette smoke (Figure 2d). Samples were exposed to 20 (1 pack) Marlboro cigarettes per day for ten days. At intervals between exposures, samples were stored in artificial saliva (1.5 mM Ca, 0.9 mM Pi, 150 mM KCL, 0.05 lg F/mL, 0.1 M Tris buffer (PH=7)) at 37º C to simulate clinical situations when not exposed to smoking conditions. Every 24 hours, the samples were washed with distilled water and soaked in fresh artificial saliva solution to prevent precipitation. Control samples (PEEK) were stored without removal for 10 days in the same artificial saliva solutions. After ten days of incubation, color measurements were made with the same technique. Due to residual irregularities left on the surfaces of the samples after exposure, the samples were brushed to remove the gross amounts of residue collected. The study aimed to measure the staining of the material rather than by spectrophotometer of the residue deposition on the surface, and therefore it was decided that the most appropriate measure of a color change would be after the removal of these deposits. The samples ere subjected to a 10/1 min brushing cycle in a brushing simulator (Biopdi, São Carlos, Brasilia) (Figure 2e) as a previously published study (Alandia-Roman, Cruvinel, Sousa, Pires-De-Souza, & Panzeri, 2013). Brushing was done underwater with 200 grams with a soft-bristled toothbrush (Colgate Microfine Black, Turkey). After brushing, color measurements of the samples were made using the same technique. Color changes ($\Delta E = [(L_2^*-L_1^*)^2 + (a_2^*-a_1^*)^2 + (b_2^*-b_1^*)^2]^{1/2}$) were calculated for each sample using L*, a*, b* values. Statistical analysis was performed at the 95% confidence level (α = 0.05) between the control and experimental groups at each surface finish for each material. The independent variable includes exposure to smoke, while the dependent variable is color change before and after treatment.

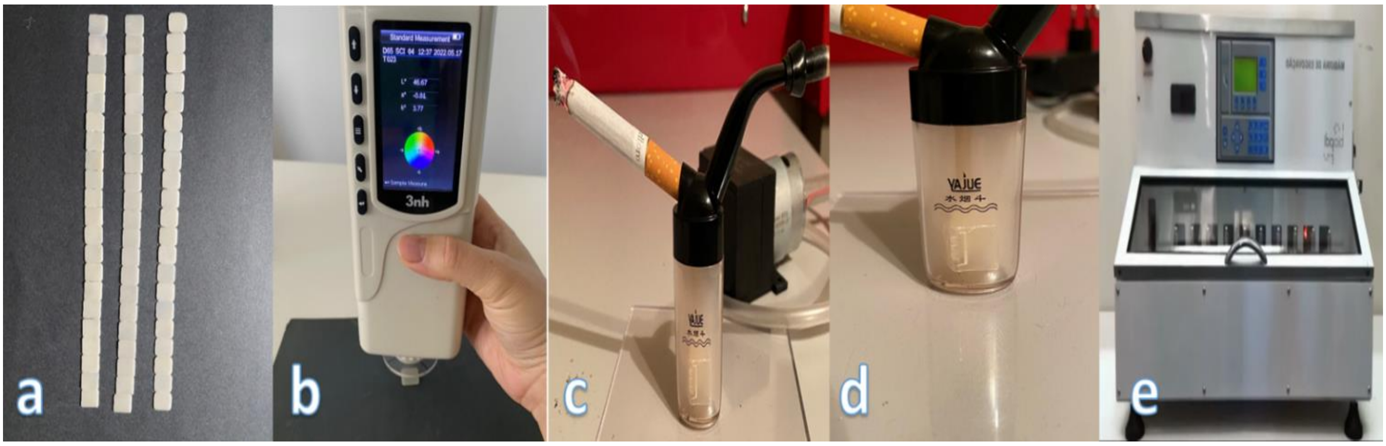

Figure 2: (a) prepared samples, (b) color measurement, (c) smoking chamber, (d) vertical sample inside the chamber and cigarette smoke, (e) tooth brushing simulator.

Statistical Analysis

Statistical analysis software for data using statistical software SPSS (V. 2.0, IBM, NY, US) was performed. Descriptive tests (mean, Levene's Test of Equality of Error Variances, Tests of Between-Subjects Effects) were applied in the data analysis. Then the following statistical tests were used.

a. Two-way ANOVA analysis of variance was used for differences between independent variables: surface (glazed and polished), time (baseline, after exposure/aging, after brushing), and type of exposure (smoking or aging).

b. Post-hoc Tamhane tests were used for all statistically significant interactions and isolated factors.

RESULTS

Levene's analysis of the variance test showed that group variances were not equal (Table 1). Statistical significance was found between covariant dependent variables (test process and group) and discoloration (Table 2). There was a statistically significant difference between the color changes of the test groups after the test procedures ($p<0.05$). While the lowest color change was found in the PEEK group after smoking and brushing, the highest value was found in the EP (e.max CAD polished) group. Color change after thermocycler and smoking was significant between the groups. The lowest discoloration was found in the EG (e.max CAD glazed) group, while the highest value was found in the ZP (zirconia polished) group. It was determined that smoking affected the test materials' clinically accepted color change values. In dentistry, a discoloration greater than detectable ($\Delta E > 1.0$) is considered acceptable up to a ΔE of 3.3; change above this value is considered unacceptable (Table 3).

Table 1: Levene's Test of Equality of Error Variances[a]

Dependent Variable: ΔE (Discoloration)			
F	df1	df2	Sig.
5.082	9	90	0.000

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Process + Group

Table 2: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3081.333[a]	5	616.267	37.821	0.000
Intercept	13906.543	1	13906.543	853.472	0.000
Process	2789.430	1	2789.430	171.193	0.000
Group	291.903	4	72.976	4.479	0.002
Error	1531.644	94	16.294		
Total	18519.520	100			
Corrected Total	4612.977	99			

Dependent Variable: ΔE (Discoloration)

a. R Squared =0.668 (Adjusted R Squared = 0.650)

Table 3: ΔE (Discoloration)

Process	Group	N	Mean*	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum	Between Component Variance
Smoked +Brushed	EG	10	19.72[a]	4.00	1.49	16.35	23.09	11.20	24.18	
	EP	10	21.22[b]	2.80	0.88	19.21	23.22	16.90	25.09	
	ZG	10	18.97[c]	2.86	0.90	16.92	21.02	13.81	22.93	
	ZP	10	16.17[,b]	1.78	0.56	14.89	17.45	12.80	19.94	
	PK(control)	10	9.27[a,b,c]	1.63	0.51	8.10	10.44	6.28	12.06	
Aged +Brushed	EG	10	2.45[a]	0.38	0.12	2.17	2.73	2.05	3.44	
	EP	10	4.27[b,c]	2.02	0.64	2.82	5.72	2.41	9.13	
	ZG	10	7.22[a]	2.30	0.73	5.57	8.87	4.49	10.99	
	ZP	10	10.37[a,b,c]	1.64	0.52	9.20	11.55	8.56	12.79	
	PK(control)	10	8.02[a,b]	1.56	0.49	7.09	9.34	5.48	10.80	
Total		100	11.79	6.82	0.68	10.43	13.14	2.05	25.09	
Model	Fixed Effects			2.42	0.24	11.31	12.27			
	Random Effects				2.12	6.97	16.61			44.77

EG= lithium disilicate glazed, EP= lithium disilicate polished, ZG= zirconia glazed; ZP= zirconia polished, PK= PEEK polished (control group). *The mean difference is significant at the 0.05 level. Same superscript letters indicate a statistical difference.

DISCUSSION

All materials used in this study are susceptible to staining when exposed to cigarette smoke. These results are consistent with past studies investigating the stainability of dental materials. Motro and Kursoğlu et al. reported a significant color change in the ceramic when immersed in coffee (Motro, Kursoglu, & Kazazoglu, 2012). Palla et al. reported significant staining of E.max lithium disilicate when immersed in various liquids such as tea, coffee, and wine (Palla et al., 2018).

Similarly, Santos et al. reported significant color change upon immersion in beverages such as cola, orange juice, coffee, and wine. Finally, Alandia-Roman's study of the effects of cigarette smoke on composites reported that significant color variation was noted among all composites exposed to cigarette smoke (Alandia-Roman et al., 2013).

Although we did not directly compare the quantitative color change between 3 different materials in our study, we investigated the color change of the same material against various surface treatments. No study compared each material's glazed and polished surfaces for lithium disilicate and zirconia. Studies reveal that polished surfaces are rougher than glazed surfaces (Palla et al., 2018). There is no consensus in the literature about the correlation between roughness and stainability, but a direct relationship is noted between surface roughness and stainability when exposed to staining agents. Some studies did not find a statistically significant interaction between roughness and stainability, such as Yuan (Yuan et al., 2018). The results of this study are consistent with Yuan et al. A more remarkable color change occurs with polished surfaces but is not statistically significant.

The properties of a material are determined by its chemical composition, structural configuration, and iatrogenic manipulation of the material. The grinding and polishing process affects the surface roughness of a material. This directly relates to the color change of the material (Palla et al., 2018). Similarly, the internal chemical composition of the material can affect discoloration. The chemical composition of E.max CAD includes 70% lithium disilicate crystals embedded in a glassy matrix. The internal crystal structure of E.max CAD is highly rough and heterogeneous at the scanning electron microscope level (Figure 3a) (Documentation, 2015). In the manufacture of the material restoration, it is milled by the diamond burs. This results in a surface roughness characterized by the roughness of the bur used for milling and the material.

The glaze applied afterward creates a more homogeneous, glassy surface on the material that covers the rough E.max CAD crystal structure (Figure 3b). Zirconia has an internal cubic, and tetragonal structural lattice reported unique to its material and a relatively smooth surface (Figure 3e). Restoration fabrication Similar to E.max, the zirconia is milled through a diamond bur to obtain restoration. The roughness of the material surface of this restoration is characterized by the structural properties of the material as well as the roughness of the diamond bur used for milling. After sintering, a glaze is applied to reach the final material surface of the restoration. PEEK differs from ceramic in its structural properties, chemical composition, and manufacturing process. Because PEEK is a methacrylate polymer, the manufacturing process involves free radical polymerization under high heat and pressure to obtain a restorative material that is 99.5% PMMA (polymethylmethacrylate). Conventional polymers such as PMMA are characterized by decreased density, increased porosity, heterogeneity, roughness, and reduced degree of polymerization due to their processing.

In addition, the physiomechanical properties of the tested materials, such as water absorption, solubility, and Marten's hardness (HM), must be considered. In another study, no correlation was observed between these characteristics and the tendency for discoloration. PEEK shows the lowest water absorption, solubility, and HM values than PMMA-based and composite resin materials. The results can be explained by the higher amount of resin matrix resulting in higher water absorption with lower filler particle content. These materials are susceptible to staining by hydrophilic colorants in aqueous solutions that increase over a more extended storage period. According to another study, water storage and thermal cycling did not affect the HM of the composite resin materials tested (Heimer, Schmidlin, & Stawarczyk, 2017)

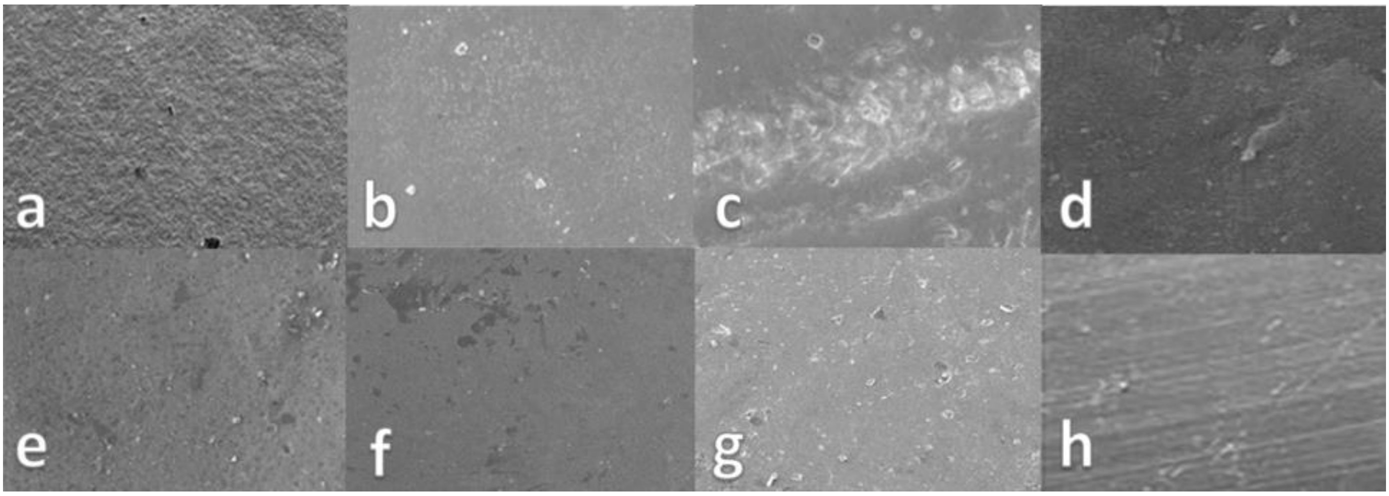

Figure 3: SEM micrographs of test materials at 100x. Non-treated IPS e.max surface (a), glazed IPS e.max surface (b), polished IPS e.max surface (c), non-treated zirconia surface (e), glazed IPS e.max surface (f), polished IPS e.max surface (g), non-treated PEEK surface (d), polished PEEK surface (h). (d), polished PEEK surface (h).

In a study evaluating the color change of PEEK, PMMA, and composite resin CAD/CAM materials and the stain removal potential of personal/professional prophylaxis and different cleaning methods, the materials were kept in different solutions (distilled water, chlorhexidine, red wine, and curry solution) for seven days. Researchers have found that PEEK material is more resistant to coloring agents than other base materials.

They reported that personal cleaning with toothbrushes effectively cleaned the materials tested in the study and the use of air abrasion devices containing fine-grained dust in professional procedures. It has been suggested that laboratory procedures for cleaning these materials include gentle cleaning processes such as ultrasonic bathing (Heimer et al., 2017).

High surface roughness is associated with increased initial biofilm adhesion. It should be investigated which parameters mainly affect bacterial attachment and growth. Previous studies have confirmed that PEEK surfaces with low surface roughness (< 0.2 μm) and free energy show significantly less bacterial growth (Bollen, Lambrechts, & Quirynen, 1997). Both nonspecific plaque deposition and the color conversion process of biofilms cause discoloration. However, the user must balance the harm and benefit of used cleaning devices. There was no plaque presence in this study. It suggests that the low coloration value is directly related to the materials' surface roughness and low surface energy.

This study found that the color change values caused by smoking in the test materials were higher than the clinical acceptability values. Brushing reduces discoloration caused by smoking. Glaze and polish processes are effective in color changes against smoking habits. New restorative materials against smoking and their polishing, finishing, and cleaning processes should be developed.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, R.K. and N.C.; methodology, R.K.; software, R.K.; validation, R.K., N.C.; formal analysis, R.K.; investigation, R.K.; resources, R.K.; data curation, R.K.; writing—original draft preparation, R.K and N.C.; writing—review and editing, N.C.; visualization, R.K.; supervision, R.K.; project administration, R.K.; funding acquisition, N.C. All authors have read and agreed to the published version of the manuscript.

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