In Vitro Effect of Tea, Coffee, and Cigarette Smoking on Color of Low-Fusing Porcelains

Düşük Isı Porselenlerinin Rengine Çay, Kahve ve Sigara Dumanının İnVitro Etkisi

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ABSTRACT Objective: Discoloration of porcelain materials can result in patient dissatisfaction and additional expense for replacement. The color stability of dental ceramics currently used for metal ceramic crowns is unknown. The purpose of this study was to determine the color stability of 4 different low-fusing dental porcelain materials against tea, coffee and cigarette smoke. **Materials and Methods:** Sixty disc-shaped specimens (12 mm in diameter and 1.5 mm in thickness) were fabricated with 4 dental porcelain materials (D-Sign, Finesse, Omega 900, VM7) according to manufacturers'; instructions. Specimens were divided into 3 subgroups for exposure to 1 of the following 3 environments: tea, coffee, and cigarette smoke. The color parameters (L*, a*, b*) of each specimen was measured with a colorimeter prior to experiment, after exposures of 1 day, 10, 20, 30, and 45 days. Further color measurements were made after brushing of specimens to determine the residual staining. Color change (ΔE) was calculated and data were analyzed with 2-way ANOVA. **Results:** There were no significant differences among color change of porcelain materials; however, the difference among staining agents was significant. Cigarette smoke produced the highest discoloration (ΔE= 18.71) in all porcelain materials followed by coffee (ΔE= 2.13) and tea (ΔE= 2.11) solutions. Before brushing, tea and coffee produced the similar discoloration in all materials tested. All staining agents increased discoloration of porcelain surfaces up to 45 days. After brushing cigarette smoke again caused the highest discoloration (ΔE= 2.65) in all porcelains followed by coffee (ΔE= 2.02) and tea (ΔE= 1.21). **Conclusion:** The stains on porcelain surfaces were effectively removed by brushing. After brushing tea solution caused slight color change and cigarette smoke and coffee solution caused noticeable color changes in all porcelains tested.

Key Words: Dental porcelain; prosthesis coloring; smoking; coffee

ÖZET Amaç: Porselen dişlerin renklenmesi hastanın hoşnutsuzluğuna ve ilave olarak protezin değişim masrafına neden olabilir. Son yıllarda yeni kullanılmaya başlanan dental porselenlerin renk stabilitesi bilinmemektedir. Bu çalışmanın amacı 4 farklı düşük ısı porseleninin renk stabilitesine çay, kahve ve sigara dumanının etkisinin incelenmesidir. **Gereç ve Yöntemler:** 60 adet disk (12 mm çapında ve 1.5 mm kalınlığında) şeklinde örnek üretici talimatlarına göre 4 dental porselen materyalinden (D-Sign, Finesse, Omega 900, VM7) üretildi. Örnekler çay, kahve ve sigara dumanına maruz bırakılmak için 3 alt gruba ayrıldı. Herbir örneğin renk parametreleri (L*, a*, b*) bir kolorimetre yardımıyla başlangıçta, 1, 10, 20, 30 ve 45'er günlük maruz bırakmalar sonunda ölçüldü. İlaveten fırçalamadan sonra kalan renklenmeyi tespit etmek için tekrar renk ölçümü yapıldı. Renk değişimleri (ΔE) hesaplandı ve verilere iki yönlü ANOVA analizi uygulandı. **Bulgular:** Porselen materyaller arasında renk değişimi açısından fark bulunamadı. Ancak boyayıcı ajanlar arasında fark istatistiksel olarak anlamlıydı. Fırçalama yapılmadan sigara dumanı (ΔE= 18.71) tüm porselen materyallerde en fazla renklenmeye neden olmuştur. Bu grubu kahve (ΔE= 2.13) ve çay (ΔE= 2.11) izlemiştir. Kahve ve çay test edilen materyallerde benzer renklenme oluşturmuştur. Tüm boyayıcı ajanlar 45 güne kadar renklenmeyi arttırmışlardır. Fırçalamadan sonra yine sigara dumanı (ΔE= 2.65) en yüksek renklenmeyi gösterirken bunu kahve (ΔE= 2.02) ve çay (ΔE= 1.27) izlemiştir. **Sonuç:** Fırçalamayla porselendeki renklenmeler önemli ölçüde azalmaktadır Ancak yine de çay tüm porselenlerde hafif bir renklenmeye yol açarken kahve ve sigara dumanı klinik olarak fark edilebilir bir renklenmeye neden olmuşlardır.

Anahtar Kelimeler: Diş porseleni; protezi renklendirme; sigara içme; kahve

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Several materials such as gold, metal supported porcelain, all ceramic, and castable ceramics are used for fabricating full coverage dental restoration depending on the esthetic and functional requirements.[1] Among these materials, metal-ceramic restorations have been the most frequently prescribed for approximately 40 years. During this period, substantial improvements in alloy substrates and veneering porcelains have resulted in the widespread acceptance of metal-ceramic restorations.[2] Metal-ceramic restorations combine the strength and accuracy of cast metal with the esthetics of porcelain.[3] In the laboratory, dental porcelain is fired, and a glazed restoration results with a surface texture and appearance resembling that of a natural tooth surface.[4]

Color stability is crucial for the success of any crown and bridge-veneering material.[5] Discoloration of dental materials can result in patient dissatisfaction and additional expense for replacement. Coloring solutions such as, coffee, tea, beverages, clorhexidine, cola, and nicotine are known to cause staining of teeth and dental restorations.[6-8] Among these, coffee, tea, and cola are known to cause heavy staining on dental restorations and appliances.[6] Staining of a restoration by colorants in a service environment may be more largely responsible for color change than color instability of the material itself.[6,9] The extent of discoloration in the oral cavity may be associated with dietary habits.[10]

Several ceramic systems have been introduced to the market with promises of excellent color match, longevity, and compatibility.[11] Although dental porcelain was thought to be a color-stable aesthetic material in previous studies,[1,5,12,13] surprisingly, in a few studies,[6,11] some porcelain material was found to be stained by the coloring solutions. It is well known that the integrity of the glaze of a dental porcelain restoration decreases the roughness of the porcelain surface and thus minimizes staining.[6]

The long term color stability of the lower fusing porcelain materials have been investigated.[5,13-15] But the long term effect of different staining agents on these porcelain materials is unknown. Seghi et al[12] demostrated that color measurement using a colorimeter provides consistent color evaluation on the porcelain surfaces. Colorimeters often report color using the CIELAB a method which was developed for characterizing color based on human perception in 1978 by the Commission Internationale de I'Eclairage. It designates color according to 3 spatial coordinates. L*, a* and b*, where L* represents the brightness (value) of a shade, a* represents the amount of red-green color, and b* represents the amount of yellow-blue color.[7,16,17] The use of a colorimeter permits some degree of quantitative analysis of color difference[10] but, the clinical significance of the value of color differences has yet to be established. Goldstein and Schmitt[18] proposed that a ΔE greater than 0.4 can already be detected by the highly trained human eye. Several studies[5,6,10] claimed that ΔE values lower than 3.3 are acceptable for tooth colored restorative materials however ΔE values greater than 2 were considered visually perceptible.[9,12,19] To relate the amount of color change (ΔE) recorded by the spectrophotometer to a clinical enviroment, ΔE values can be decribed thought the equation NBS (National Bureau of Standards) units= ΔE X 0.92. Critical remarks of color differences as expressed in terms of NBS units are shown in Table 1.[14,20,21]

The purpose of this study was to determine the color stability of 4 different low-fusing porcelain

TABLE 1: The porcelain materials and their manufacturers

Porcelain materials	Lot numbers	Manufactures
D-Sign	E37780	Ivoclar Vivadent AG, Schaan, Liechtenstein
Finesse	02041811	Ceramco, Burlington, NJ. USA
Omega 900	7411	Vita Zahnfabrik, Bad Sackingen, Germany
VM7	7549	Vita Zahnfabrik

materials against tea, coffee and cigarette smoke. The hypothesis for this study was that the low-fusing porcelain materials (D-Sing, Finesse, Omega 900 and WM7) have different rates of color change after exposure to tea, coffee, cigarette smoke.

MATERIAL AND METHODS

Sixty disc-shaped specimens (12 mm in diameter and 1.5 mm in thickness) were fabricated with 4 low-fusing dental porcelain materials (n= 15). The porcelain materials and their manufacturers are shown in Table 2. Porcelain specimens were prepared using a round split mold made of polyvinyl siloxane putty thus incisal porcelain could be applied in a thickness of 2 mm. The porcelain was condensed until no liquid appeared on the surface. Specimens were trimmed flush with the top of the mold, removed from the mold and placed on a firing tray. Each porcelain specimen was fired once, according to the manufacturer's recommendations. After firing, all specimens were ground flat on one side to achieve approximately uniform thickness and glazed according to manufacturers' instruction. The final thickness of porcelain specimens was 1.5 mm as in previous studies.[1,14] Fifteen specimens of each group were divided into 5 specimens containing subgroups for exposure to 1 of the following 3 environments: tea, coffee, and cigarette smoke.

PREPARATIONS OF STAINING ENVIRONMENTS

Specimens selected from each material were exposed to 1 of the following conditions: coffee or tea and kept in the dark at 37 ± 1°C for 45 days. To prepare a standard solution of coffee, 15 g of coffee (Nescafe Classic; Nestle, Istanbul, Turkey) was poured into 500 mL of boiling distilled water. After 10 minutes of stirring, the solution was passed through filter paper. The tea solution was prepared by immersing 5 tea bags (Lipton Yellow Label Tea, Istanbul, Turkey) into 500 mL of boiling distilled water for 10 minutes.

The smoke exposure system consisted of a glass chamber, a pump, and a fan as similar to that used in previous studies (Figure 1).[22,23] The fan was attached to the glass chamber of the smoking machine. The pump was used to push the air through the burning cigarette into the glass chamber. One volume cigarette smoke was mixed with one volume of room air in the dilution chamber using a rotating fan. During smoke exposure, specimens were placed in the chamber and inhaled 50% of cigarette smoke. Each filter cigarette was burned for approximately 8-10 minutes and a total number of 20 cigarettes were used each day. 'Maltepe' cigarettes (Tekel Cigarette Factory, Istanbul Turkey) manufactured from a blend of Turkish tobacco were used in the study.

TABLE 2: National Bureau of Standards (NBS) ratings.

NBS unit	Critical remarks of color differences	
0.0-0.5	Trace	Extremly slight change
0.5-1.5	Slight	Slight change
1.5-3.0	Noticiable	Perceivable change
3.0-6.0	Appreciable	Market change
6.0-12.0	Much	Extremly market change
12.0 or more	Very much	Change to other color

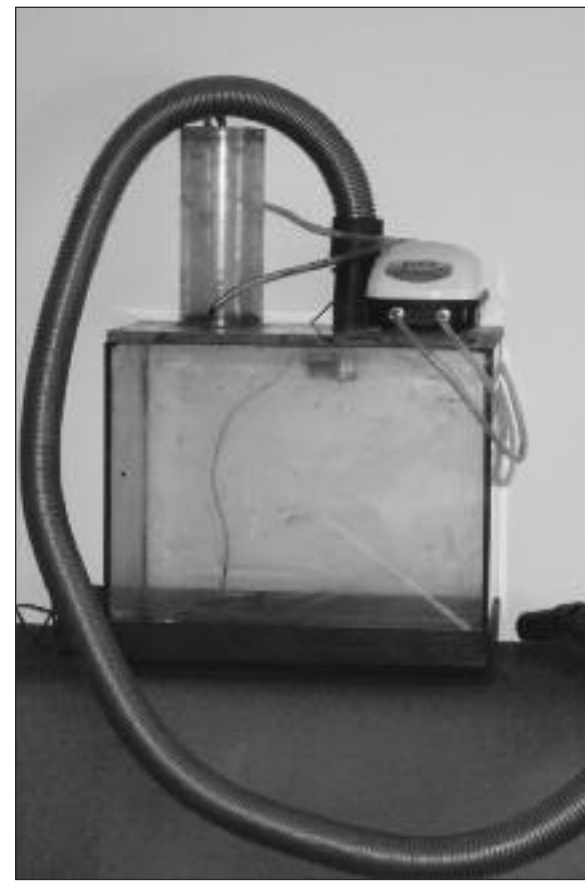

FIGURE 1: Smoke exposure system.

COLOR MEASUREMENTS

Before exposure to the staining agents, the baseline color measurement of all specimens was recorded with a colorimeter (Minolta Chroma Meter CR 300, Minolta Inc Osaca Japan). The specimens were arranged so that the glazed surfaces were exposed for the application of the coloring agents. Color measurements were taken on 1st, 10th, 20th, 30th, and 45th days. Prior to the recordings being obtained; the specimens were removed from the containers and thoroughly rinsed in distilled water and dried with tissue paper. After taking the 45th day's data, all specimens were gently brushed with a toothbrush and then measurements were repeated. Color parameters in L*a*b* color space were recorded with a small area colorimeter as in previously described.[1,6,9,12,15,24]

The colorimeter was set to the multi-measure mode in which 3 readings were automatically taken for each specimen. The mean value of these 3 readings was recorded. The white calibration standard was used as the background for each specimen during data collection to standardize the effects of background color during measurements. The color difference (ΔE) between the interval and baseline was calculated from the following equation:

$$\Delta E = [(L_1-L_2)^2 + (a_1-a_2)^2 + (b_1-b_2)^2]^{1/2}.$$

Where L_1, a_1, b_1 represent pre-experimental color values of each sample and L_2, a_2, b_2 represent post-experimental color values of each sample. Then the data were converted NBS units using the equation of NBS unit (NBS unit = ΔE X 0.92). Statistical analysis was carried out using the program SPSS 11.0 for Windows version. Data were analyzed with 2-way ANOVA (α= .05).

RESULTS

The mean ΔE values with the standard deviations of each porcelain group exposed the staining agents at the time intervals and after brushing are shown in Table 3. The mean color differences converted to NBS units are given Table 4.

TABLE 3: Mean color change (ΔE) values with the standard deviations of all porcelain groups against to staining agents at time intervals.

Porcelains	Staining agents	1 Day	10 Days	20 Days	30 Days	45 Days	After brushing
IVOCLAR D SIGN	Tea	0.48 ± 0.29	1.16 ± 0.23	1.42 ± 0.29	1.68 ± 0.51	2.82 ± 1.05	0.46 ± 1.11
	Coffee	0.04 ± 0.14	0.81 ± 0.55	1.66 ± 0.56	1.88 ± 0.48	3.05 ± 0.89	0.91 ± 0.28
	Cigarette Smoke	1.71 ± 0.82	18.31 ± 0.91	26.21 ± 0.96	28.33 ± 0.68	29.88 ± 1.89	1.21 ± 0.24
FINESSE	Tea	1.52 ± 1.54	1.90 ± 1.63	2.47 ± 2.42	2.73 ± 2.42	2.76 ± 1.97	2.42 ± 0.89
	Coffee	1.29 ± 1.23	1.29 ± 1.53	1,32 ± 1.59	1.44 ± 1.23	1.46 ± 1.23	1.49 ± 1.17
	Cigarette Smoke	6.23 ± 2.67	17.45 ± 1.56	25.42 ± 1.87	26.09 ± 2.27	30.04 ± 1.53	3.23 ± 1.78
VITA OMEGA 900	Tea	0.60 ± 0.34	2.49 ± 0.94	2.74 ± 0.87	2.86 ± 1.21	3.31 ± 1.32	0.19 ± 0.81
	Coffee	0.89 ± 0.68	1.88 ± 0.76	3.23 ± 1.32	4.92 ± 1.53	4.96 ± 1.45	3.31 ± 1.85
	Cigarette Smoke	4.54 ± 2.78	21.03 ± 1.76	28.00 ± 3.12	30.79 ± 1.41	32.40 ± 3.42	4.96 ± 1.85
VITA VM7	Tea	1.25 ± 1.13	2.83 ± 1.21	3.42 ± 1.38	3.49 ± 1.41	3.78 ± 1.23	1.23 ± 1.01
	Coffee	1.04 ± 0.79	1.56 ± 0.93	3.40 ± 1.22	3.59 ± 1.42	3.63 ± 1.36	2.39 ± 0.34
	Cigarette Smoke	3.65 ± 1.03	18.28 ± 3.21	28.20 ± 1.62	28.98 ± 1.75	32.26 ± 1.63	2.75 ± 2.01

TABLE 4: Mean National Bureau of standards (NBS) values of staining agents at time intervals.

Staining agents	1 Day	10 Days	20 Days	30 Days	45 Days	After brushing
Tea	0.89	1.93	2.32	2.47	2.92	1.11
Coffee	0.71	1.28	2.21	2.72	3.02	1.86
Cigarette Smoke	3.72	17.27	24.80	26.27	28.66	2.62

Omega 900 porcelain showed most discoloration. However, color change values were found to be similar among the porcelain groups for all staining agents and at all time intervals (*P*= .89), (Figure 2).

Before brushing, tea (ΔE= 2.11) and coffee (ΔE= 2.13) showed similar color change values; whereas, cigarette smoke (ΔE= 18.77) resulted in greater discoloration (*P*= .00), (Figure 3) in all porcelain materials.

Color change of porcelain groups against tea and coffee were similar at all time intervals and less than 3.3 ΔE (3 NBS) values. However, cigarette smoke staining increased up to 20 days and it remained stable after 20th day. It was found that the value of ΔE for cigarette smoke staining was higher than 3.3.

After porcelain specimens were brushed, the values of ΔE were significantly decreased (Figure 4).

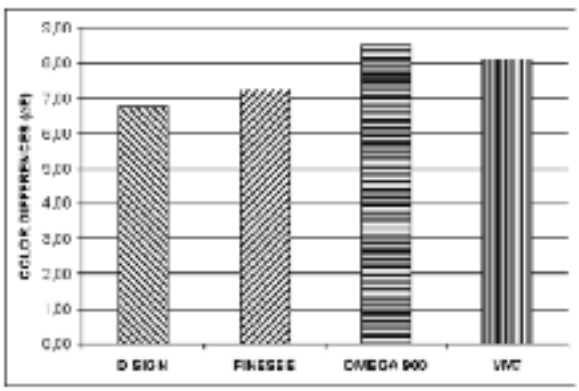

FIGURE 2: Mean color change (ΔE) values of porcelain groups against to staining agents.

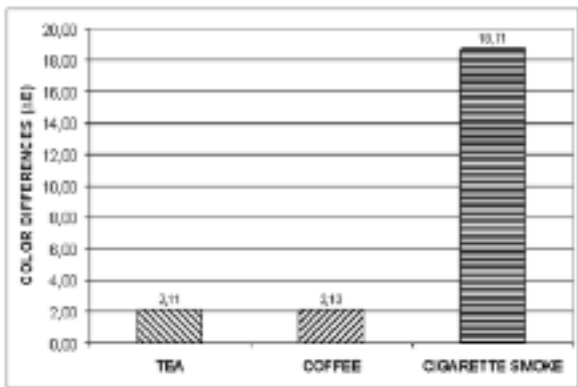

FIGURE 3: Mean color change (ΔE) values of staining agents (before brushing).

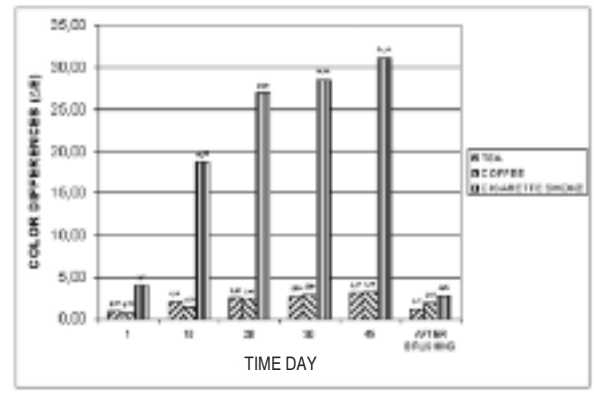

FIGURE 4: Mean color change (ΔE) values for various lengths of time.

Tea solution (1.11 NBS) caused slight color change and cigarette smoke (2.62 NBS) and coffee solution (1.86 NBS) caused noticeable color changes in all porcelain materials tested (Table 4).

DISCUSSION

All porcelain materials tested showed the same discoloration when exposed to various staining agents; coffee, tea and cigarette smoke so that the research hypothesis for this study was rejected. Cigarette smoke stained the porcelain materials more than the coffee and tea solutions before brushing. Nescafe, tea and cigarette smoke were chosen as test agents, because they have been shown to have greater staining ability on dental restoration materials.[8-10,16,25-27]

A previous study[6] revealed that the preparation and concentration of the coffee and tea affected the degree of discoloration. The solutions used in the present study were prepared closer to that of real drinks. Regular daily cigarette smokers with a current consumption of more than ten cigarettes a day are usually recorded as 'smokers', so the specimens were exposed to the smoke from 20 cigarettes a day through the machine.

Color perception by visual assessment of objects is a subjective, physiologic, and psychological process that varies between and within persons.[25,28] This variability is a result of several factors, including observed object and illuminant position relative to the observer and to each other, color characteristics of the illuminant, metamerism, fati-

gue, aging, and the emotional state of the observer. Instrumental colorimeters have been found to have accuracy for in vitro measurement of color and color differences.[12,28] Since the latter eliminates the subjective interpretation, colorimetric technique was used in this study.

In this study, discoloration of porcelain materials against staining agents (coffee, tea and cigarette smoke) was investigated for 45 days. In in vitro color stability studies, a period of for week's immersion may be considered to be too long. However, to reach the cumulative staining results of these solutions, it was decided to continue testing until the end of a period of 4 weeks.[25,29] Similarly, in the present study, the color stabilities of porcelain specimens were also measured for 45 days. After 45 days all tested porcelain groups showed lower color change in coffee and tea solution, which were less than 3.3 ΔE units, the highest value that has been determined as clinically acceptable. However, ΔE values were greater than 2ΔE units which were considered visually perceptible. Cigarette smoke caused the most significant color change, which was higher than 3.3 ΔE units. It has been determined as clinically unacceptable. In this study also the effect of the brushing procedure was seen as a reduction of the ΔE values for the specimens treated with tea, coffee and cigarette smoke. Especially the reduction of the ΔE was the most in cigarette smoke group. Because of this, the possible plasticizing effect of cigarette tar and the cigarette smoke stain can be removed with mechanical cleaning (brushing). Rinsing water alone is not enough to remove the stains from porcelain surfaces.

This result of the study indicated that mechanical cleaning (brushing) is important for reduction of discoloration of porcelain materials. This finding is similar to results from previous studies.[10,26,27]

Several studies demonstrated that coffee produced greater color changes than tea. However, Khokhar et al[26] and Polyzois et al[30] showed that tea had higher staining effects than coffee on resin materials. In the present study tea and coffee produced similar discoloration on low-fusing porcelain materials for 45 days however, after brushing, tea staining was less noticeable. While tea caused slight color change, coffee and cigarette smoke caused noticeable color change in porcelains.

When discussing the clinical applications of these results, it must be considered that the oral environment differs in several ways from in vitro conditions. Factors such as the variety of food, thermal and mechanical stresses, and their interactions may intensify discoloration in vivo.[9] Beside this, tongue, cheek, lip and saliva in the mouth all provide physiological cleaning of tooth crowns.

Color changes to the restoration are affected by many parameters including the type of materials used for the restoration as well as the diet and oral hygiene of the patient. The color of porcelain materials tested can be changed depending on the dietary factors (coffee and tea), smoking and regular oral hygiene of patients.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. All porcelains tested exhibited the same color changes after exposure to staining agents.

2. Before brushing tea and coffee solutions produced similar discoloration in the materials tested. Cigarette smoke caused more discoloration than the tea and coffee.

3. After mechanical cleaning, the discoloration of staining agents (especially cigarette smoke) on the porcelain materials tested was reduced. While tea caused slight color change, cigarette smoke and coffee caused, noticeable color change in porcelain materials clinically.

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