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Effects of Staining Beverages and Office Bleaching Agents on the Optical Characteristics and Surface Topography of Maxillary Incisor Teeth

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Abstract

BACKGROUND/AIMS: The aim of this study was to evaluate the staining abilities of different beverages, the efficacy of two office bleaching agents and the effect of bleaching on the surface topography of maxillary incisors.

MATERIALS AND METHODS: Sixty crowns of maxillary incisors were obtained and immersed in distilled water for 24 hours. After baseline color measurements were made, the specimens were divided into three groups according to three immersion solutions [Turkish coffee (TC), red wine (RW), and distilled water (DW)]. At the end of the staining period, color measurements were repeated and then the specimens of each group were divided into two subgroups and Perfect Bleach Office+ (PBO+) or Opalescence Boost (OB) were applied. After bleaching, the color measurements were recorded again and the optical parameters of color difference (ΔE00), changes in the translucency parameter (ΔTP00) and whiteness difference (ΔWID) were calculated. For the surface analysis, atomic force microscopy was performed for one specimen from each group.

RESULTS: The highest color changes were observed with RW ($p<0.05$). Although TC showed high color changes, no significant difference was observed with the control group ($p=0.208$). The observed color and whiteness differences were higher than the acceptability thresholds ($\Delta E00>1.8$ and $\Delta WID>2.60$) and the ΔTP00 values were lower than the acceptability thresholds ($0.62<\Delta TP00<2.62$). Regardless of the type of staining solution, OB showed higher ΔE00 values ($p=0.000$). Surface roughness observed after bleaching was not higher than the critical surface roughness (0.2 µm). Differences in the surface topography of the specimens relating to the solution type were observed.

CONCLUSION: The frequent consumption of Turkish coffee and red wine can cause discolorations. Surface analysis showed that office bleaching agents can be a safe method for the treatment of discolorations with a high efficiency in color and whiteness reversal.

Keywords: Atomic force microscopy, bleaching, color, surface roughness, whiteness

INTRODUCTION

Dental discoloration has become one of the most important concerns of dentistry due to current changes in esthetical perceptions with regards to healthy, confident and whiter smiles.[1] The habits of patients, such as smoking, their medical history, their frequent use of mouth rinses, the accumulation of biofilm, their use of medications, and their diets, such as drinking colored beverages, are examples of the intrinsic and extrinsic factors which may cause dental discoloration.[2,3] The type, exposure times and concentrations of staining agents are the most important components determining the severity of any discoloration.[4-6]

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Currently, bleaching procedures have become more popular as a result of this major concern. Mainly, there are two types of bleaching methods, namely, home bleaching and office bleaching. Office bleaching, applied by dental clinicians, generally uses higher concentrations of hydrogen peroxide (H_2O_2).[2] Due to its low molecular weight, H_2O_2 can freely penetrate into the interprismatic spaces of enamel and dentin tubules and oxidize coloring pigments.[2,7]

For the judgement of color changes during office bleaching, dental clinicians generally prefer to use shade guides and digital photography. For a more objective evaluation, the most preferred method to determine any color changes in dental practices are spectrophotometers.[8,9] Spectrophotometers measure the transmittance or spectral reflectance properties of a material at 1–25 nm intervals along the visible spectrum by using a standard illuminant, observer and recommended geometry and then express these via a three-coordinate system (L*a*b), which was introduced by Commission Internationale de l'Eclairage (CIE).[10,11]

The oxidation reaction occurring during bleaching applications can cause some chemical changes in dental surfaces which can change the surface topography.[12,13] Surface roughness is an important factor which affects biofilm accumulation, which can cause the recurrence of discoloration. Atomic force microscopy (AFM) is one of the methods used for surface analysis.[14] In addition to needing minimal sample preparation and without changing the natural conditions of specimen structure, it is capable of revealing the surface along the X, Y and Z axes.[14,15] As a result, both two- and three-dimensional images of the surfaces can be obtained at the same time.

There have been studies[14,16-20] which have investigated the effects of bleaching agents on color changes or on the surface characteristics of permanent teeth by different methods. However, to the best of our knowledge, with regards to *in vitro* studies, samples were generally the intersections of enamel or dentine, with the exception of a recent study in which the color susceptibility of premolars and the efficacy of whitening toothpaste was investigated.[3] Data regarding AFM images obtained from bleached permanent teeth is limited. Thus, the purpose of this *in vitro* study was to evaluate the color stability of maxillary incisors, the staining ability of different beverages, the efficacy of two office bleaching agents and the effects on the surface characteristics of stained maxillary incisors. The determined null hypotheses were;

1- There will be no changes in the color, whiteness and translucency of permanent teeth after staining and bleaching,

2- There will be no statistically significant difference in the staining abilities of the different beverages,

3- There will be no statistically significant difference in the efficacy of the bleaching agents,

4- There will be no differences in the surface topography and roughness of the enamel surfaces relating to the bleaching agents and/or the staining beverages.

MATERIALS AND METHODS

Specimen Preparation

A statistical power analysis using the G*Power 3.1 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) software was performed with a statistical power of 80% and significance level of 0.05 (α) to determine the number of the specimens required for the present study. Sixty maxillary incisor teeth were obtained according to a protocol (YDU2016/37-287) which was approved by the Committee for Ethics of Research of Near East University. Each tooth was examined carefully and those with no caries, fractures or any other defects were included in this study. After soft and hard deposits on the teeth were cleaned, the crowns were polished using fine (particle size: 24 µm) and superfine (particle size: 8 µm) Sof-Lex™ Discs (3M ESPE, St. Paul, MN, USA) respectively. Following this, the roots were separated from the cemento-enamel junction using a water-cooled, high speed diamond bur. Before baseline color measurements were made, the crowns were washed and placed in distilled water for 24 hours.

Color Measurements

A calibrated spectrophotometer (VITA Easyshade Compact, VITA Zahnfabrik, Bad Säckingen, Germany) was used for the color measurements, which were performed at baseline, on the 14th day of staining and after bleaching. The probe of the spectrophotometer was settled flush to the middle third area of labial surfaces and the L* (lightness), a* and b* (chromatic components) parameters were recorded according to the CIE L*a*b* color space. These parameters were recorded three times for each specimen on non-reflective backgrounds (white; L=96.3, a=0.1, b=1.9 and black; L=8.9, a=-0.7, b=1.2) and the mean values were calculated. The CM-3600a spectrophotometer (Konica Minolta, New Jersey, USA) was used to obtain the L, a and b coordinates for both white and black. In accordance with the manufacturer's instructions, calibration was repeated after each nine measurements.

Immersion in Staining Solutions

After the completion of baseline color measurements, three staining subgroups of the specimens with a sample size of 20 per subgroup were formed in terms of the type of staining beverages. The specimens were immersed either in distilled water (DW) as a control, Turkish coffee (Kurukahveci Mehmet Efendi, İstanbul, Turkey) for which 30 grams were boiled with 600 mL water and then filtered or red wine (RW, 2014 Angora, Kavaklıdere Şarapları A.Ş., Ankara, Turkey) with a volume of 20 mL for 30 minutes per day. At the end of 30 minutes of staining, the specimens were rinsed thoroughly with distilled water. The specimens were immersed in 20 mL distilled water for the remaining time of 24 hours. In a pilot study,[21] the optimal contact time of a hot beverage in the mouth was reported to be 60 seconds for each cup. Thus, to simulate a total of 12 months, with an average of 420 cups/glasses of beverage consumption, staining was applied for 14 days.

Bleaching Procedure

In the present study, Perfect Bleach Office+ (VOCO GmbH, Cuxhaven, Germany) with a concentration of 35% hydrogen peroxide; and Opalescence Boost (Ultradent Products Inc., South Jordan, UT, USA) with a concentration of 40% hydrogen peroxide were used as the bleaching agents. Specimens for each staining solution were divided into two groups with a sample size of 10 for each bleaching agent. At the end of the staining period, all of the specimens were dried well using blotting paper and air flow. After the color measurements were completed, to simulate the clinical procedures, first the lingual surfaces of the specimens were polished using prophy cups. Then, the bleaching agents were applied to the labial surfaces with an approximate thickness of 1 mm. According to the manufacturers' instructions, the applications of Perfect Bleach Office+ (PBO+) and

Opalescence Boost (OB) were 15 min and 20 min respectively. During the application, the agents were activated every 5 minutes by a micro-brush. At the end of the bleaching procedure, the specimens were washed with distilled water and dried well via air flow and blotting paper.

Optical Analysis

Optical analysis were performed using the calculated mean values of L_w*, a_w*, b_w* and L_B*, a_B*, b_B* where 'W' and 'B' refer to the background colors, namely white and black, respectively.

The following equation was used for the calculations of ΔE_{00} (color difference) values to evaluate color change between the two different measurements.[22]

$$\Delta E_{00}=\left[\left(\frac{\Delta L}{k_L S_L}\right)^2 + \left(\frac{\Delta C}{k_C S_C}\right)^2 + \left(\frac{\Delta H}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C}{k_C S_C}\right)\left(\frac{\Delta H}{k_H S_H}\right)\right]^{1/2}$$

ΔL, ΔC and ΔH are the changes in lightness, chroma and hue between the baseline and subsequent color measurements. The total color difference for the variation in perceived magnitude with the variation in the location of the color coordinate difference between 2 color measurements are adjusted by weighting functions (S_L, S_C and S_H). R_T (rotation function) is a function accounting the interaction between hue and chroma differences in the blue region. The correction terms for the experimental conditions are defined by parametric factors of K_L, K_C and K_H. The computation used for the ΔE_{00} calculations of the present study was carried out with regards to CIEDE2000 (1:1:1) where the parametric factors were defined as 1.[22,23] The perceptibility threshold (PT) for ΔE_{00} values was taken to be 0.8 and the 50%:50% acceptability threshold (AT) was taken to be 1.8 for the present study.[22]

The CIEDE2000 (1:1:1) formula was also used to calculate the translucency parameter (TP_{00}) where the color coordinates of the specimen were recorded at the same period of time but on different backgrounds, namely black or white.[24]

$$TP_{00} = \left[\left(\frac{L'_B - L'_W}{K_L S_L}\right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C}\right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H}\right)^2 + R_T\left(\frac{C'_B - C'_W}{K_C S_C}\right)\left(\frac{H'_B - H'_W}{K_H S_H}\right)\right]^{1/2}$$

The changes in the translucency parameter were calculated by $\Delta TP_{00}=|TP_{00}1 - TP_{00}2|$. The PT for ΔTP_{00} value was 0.62 units and the 50%:50% AT for the ΔTP_{00} value was 2.62 units for the present study.[24]

For the examination of the whiteness during this study; a new CIELAB space based whitening index (WI_D) was used:[25]

$WI_D = 0.511L^* - 2.324a^* - 1.100b^*$

Low (even negative) values of the WI_D index show lower values of whiteness while high positive values indicate higher whiteness.[25] The PT for the ΔWI_D value was 0.72 units and the 50%:50% AT for the ΔWI_D value was 2.60 units for the present study.[26]

Atomic Force Microscopy Analysis

One specimen from each group was embedded into composite blocks forming a stable and straight surface for atomic force microscopy (XE-100E, Park Systems, Induspia 5F, SangDaewon-Dong 517-13 Sungnam, Korea) analysis. The topography of the specimens was examined with a tip working in contact mode with an average rate less than 0.7 Hz within an area of 30x30 μm^2. XEI software (Park Systems, Induspia 5F, SangDaewon-Dong 517-13 Sungnam, Korea) was used to transform the data into 2D and 3D images for topography analysis. For surface analysis, the average R_a (surface roughness), R_{sk} (skewness), and R_{ku} (kurtosis) values were measured from six different lines obtained from the 2D images for each specimen.

Statistical Analysis

Descriptive statistics were performed for all groups and the distribution of ΔE_{00}, ΔTP_{00} and ΔWI_D values were checked by a normality test (Shapiro–Wilk test). The SPSS Version 18 (SPSS Inc., Chicago, IL, USA) was used for statistical analyses and $p<0.05$ was accepted as statistically significant. For the optical parameters obtained for the differences between baseline and staining, One-Way ANOVA (Tukey for pairwise comparison) was performed for ΔE_{00}, while the Kruskal–Wallis test (Mann–Whitney U test for pairwise comparison) was performed for ΔTP_{00} and ΔWI_D. Two-Way ANOVA (Bonferroni adjusted alpha=0.05) was performed for the ΔE_{00}, ΔTP_{00} and ΔWI_D parameters obtained for the differences between staining and bleaching and also baseline and bleaching. For pairwise comparisons, the Tukey's range test was applied with 95% confidence intervals.

RESULTS

The detected mean values and standard deviations for each optical parameter are shown in Tables 1–3. While the translucency differences observed in the present study were lower than acceptability threshold ($0.62<\Delta TP_{00}<2.62$), all of the observed color and whiteness differences were higher than the acceptability thresholds ($\Delta E_{00}>1.8$ and $\Delta WI_D>2.6$).

None of the ΔTP_{00} values showed statistically significant differences during the study duration ($p>0.05$). Additionally, none of the parameters calculated for the differences between the baseline and after bleaching measurements showed statistically significant differences ($p>0.05$).

At the end of the staining period, the highest color change was observed in the RW group, which was significantly different from the control group ($p=0.001$). On the other hand, TC did not show any significant color difference with either the control ($p=0.275$) or the RW group ($p=0.108$).

When the efficacy of OB and PBO+ were compared, regardless of the type of staining solution, no significant differences were observed for

Table 1. Mean values and standard deviations of color, translucency and whiteness differences between baseline and staining

	ΔE_{00}	ΔTP_{00}	ΔWI_D
DW	4.76±3.29*	0.94±0.72	13.43±12.20
TC	7.73±3.49*,‡	0.87±0.62	17.08±13.23
RW	11.44±8.18‡	1.51±1.46	20.71±16.14

Different superscript symbols show statistically significant difference ($p<0.05$).
DW: distilled water, TC: Turkish coffee, RW: red wine, ΔE_{00}: color difference, ΔTP_{00}: translucency parameter difference, ΔWI_D: whiteness difference.

Table 2. Mean values and standard deviations of color, translucency and whiteness differences between staining and bleaching

	ΔE_{00}		ΔTP_{00}		ΔWI_D	
	OB	**PBO+**	**OB**	**PBO+**	**OB**	**PBO+**
DW	$2.88\pm0.95^{A,a}$	$4.04\pm1.86^{C,a}$	0.82 ± 0.99	0.88 ± 0.54	$5.81\pm4.15^{D,e}$	$9.67\pm3.96^{F,e}$
TC	$6.74\pm4.63^{A,b}$	$4.29\pm1.92^{C,b}$	1.23 ± 1.33	2.09 ± 2.26	$10.91\pm9.00^{D,E,f}$	$8.41\pm4.35^{F,f}$
RW	$14.45\pm6.47^{B,c}$	$4.21\pm1.76^{C,d}$	2.45 ± 1.79	0.96 ± 0.59	$16.57\pm13.48^{E,g}$	$9.84\pm4.50^{F,g}$

Different superscript lower case letters in columns and capital letters in rows indicate statistically significant differences ($p<0.05$).
DW: distilled water, TC: Turkish coffee, RW: red wine, OB: Opalessence Boost, PBO+: Perfect Bleach Office+, ΔE_{00}: color difference, ΔTP_{00}: translucency parameter difference, ΔWI_D: whiteness difference.

Table 3. Mean values and standard deviations of color, translucency and whiteness differences between baseline and bleaching

	ΔE_{00}		ΔTP_{00}		ΔWI_D	
	OB	**PBO+**	**OB**	**PBO+**	**OB**	**PBO+**
DW	3.52±2.98	5.60±1.61	0.94±0.71	1.13±1.57	8.10±8.07	12.41±10.85
TC	4.32±1.36	5.43±3.92	1.14±1.39	2.01±1.94	8.55±6.77	14.92±14.52
RW	6.24±2.06	5.18±1.80	1.02±0.68	0.76±0.47	14.07±8.92	11.22±10.83

DW: distilled water, TC: Turkish coffee, RW: red wine, OB: Opalessence Boost, PBO+: Perfect Bleach Office+, ΔE_{00}: color difference, ΔTP_{00}: translucency parameter difference, ΔWI_D: whiteness difference.

Table 4. R_a, R_{sk} and R_{ku} values obtained by AFM analysis

	R_a			R_{sk}			R_{ku}		
	Min	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**
DW, OB	0.028	0.050	0.035	-0.487	0.444	0.014	2.329	4.480	2.863
DW, PBO+	0.110	0.219	0.154	-0.687	0.357	0.179	2.084	2.991	2.692
TC, OB	0.056	0.151	0.099	-1.977	0.052	-1.002	3.006	7.369	4.587
TC, PBO+	0.028	0.103	0.064	-1.856	-0.937	-1.281	3.735	6.548	4.201
RW, OB	0.066	0.146	0.082	-1.950	0.107	-0.382	2.708	7.523	3.158
RW, PBO+	0.079	0.268	0.156	-2.762	0.470	-1.169	1.799	11.006	4.722

DW: distilled water, TC: Turkish coffee, RW: red wine, OB: Opalessence Boost, PBO+: Perfect Bleach Office+, R_a: surface roughness, R_{sk}: skewness, R_{ku}: Kurtosis, Min: minimum, Max: maximum.

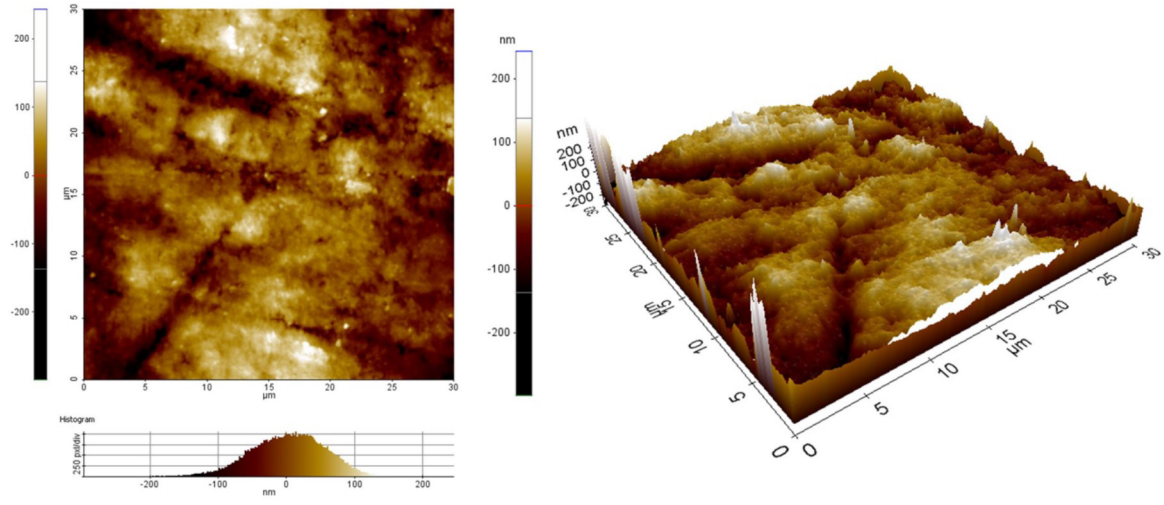

Figure 1. 2D and 3D images of OB applied DW group.
2D: two-dimensional, 3D: three-dimensional, OB: Opalescence Boost, DW: distilled water

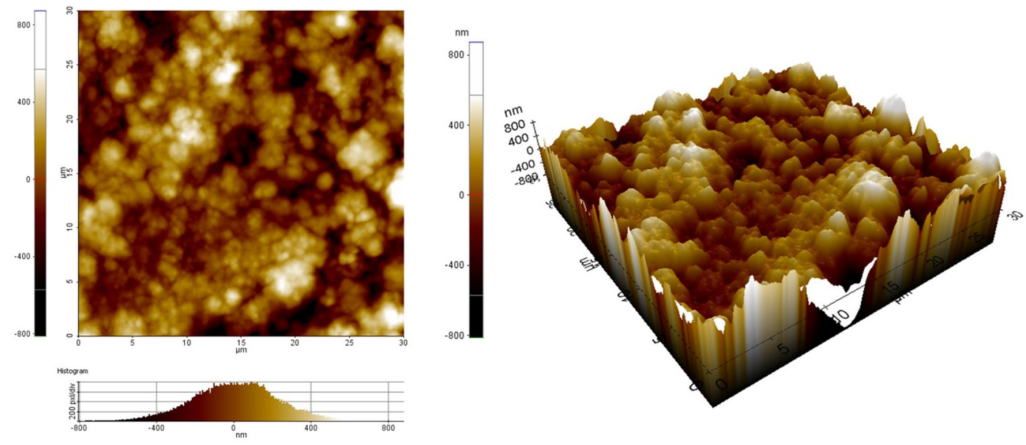

Figure 2. 2D and 3D images of PBO+ applied DW group.
2D: two-dimensional, 3D: three-dimensional, PBO+: Perfect Bleach Office+, DW: distilled water

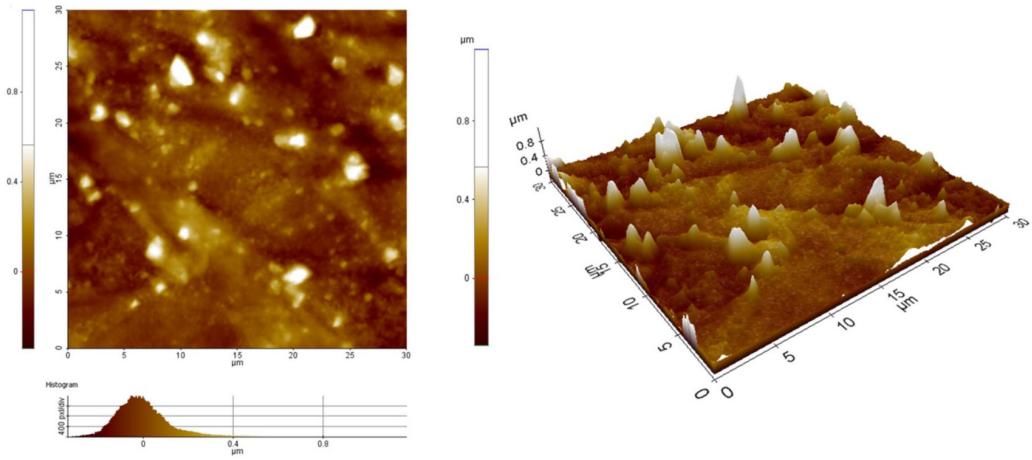

Figure 3. 2D and 3D images of OB applied TC group.
2D: two-dimensional, 3D: three-dimensional, OB: Opalescence Boost, TC: Turkish coffee

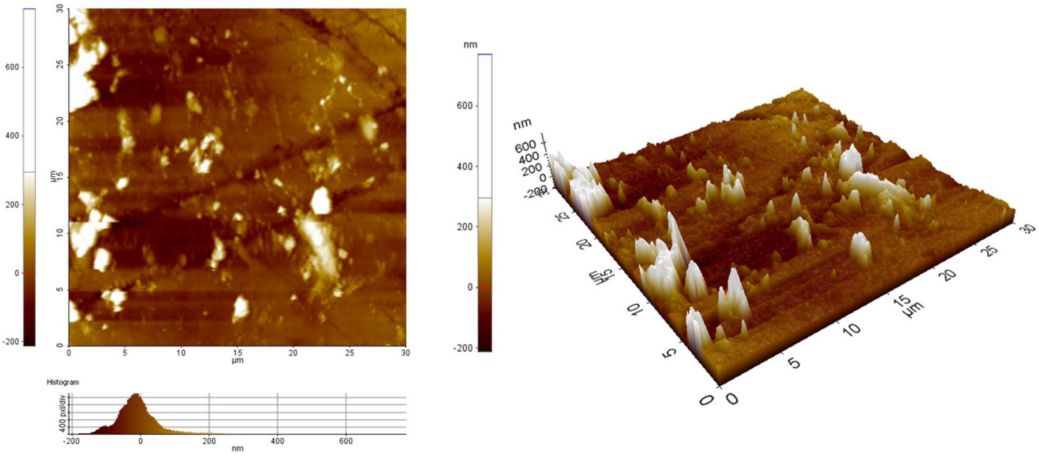

Figure 4. 2D and 3D images of PBO+ applied TC group.
2D: two-dimensional, 3D: three-dimensional, PBO+: Perfect Bleach Office+, TC: Turkish coffee

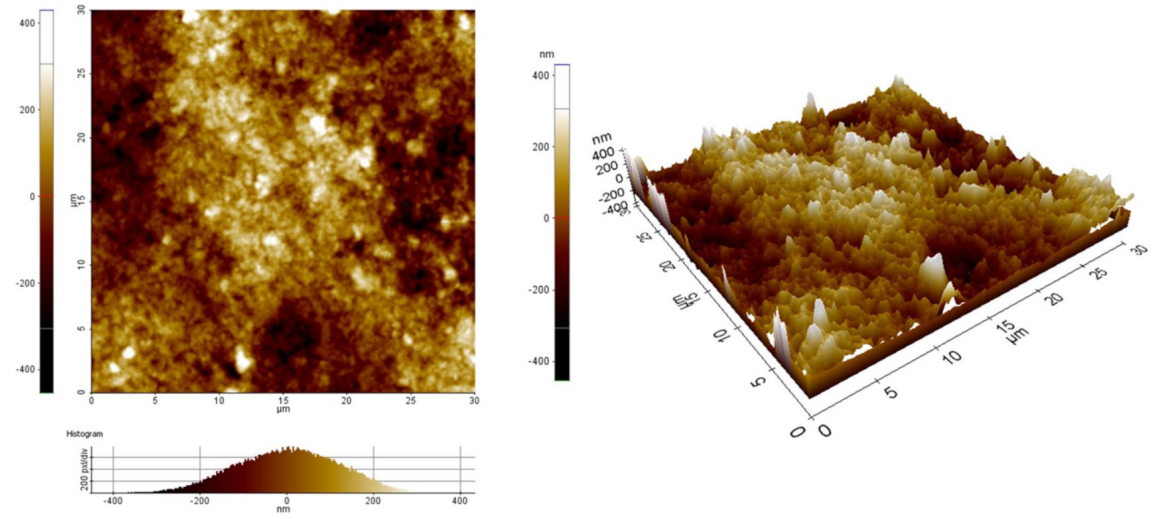

Figure 5. 2D and 3D images of OB applied RW group.
2D: two-dimensional, 3D: three-dimensional, OB: Opalescence Boost, RW: red wine

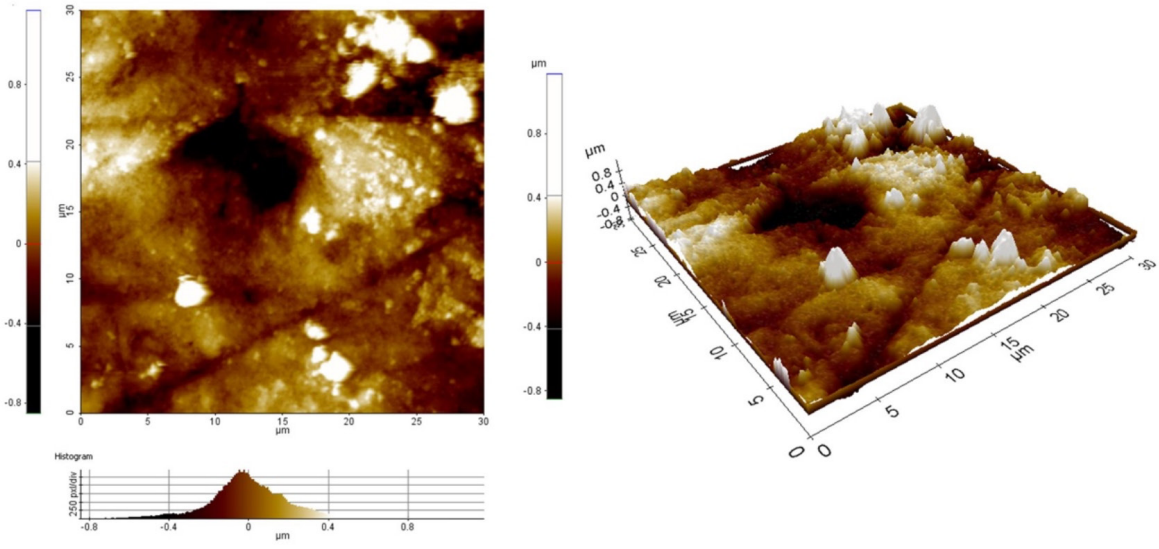

Figure 6. 2D and 3D images of PBO+ applied RW group.
2D: two-dimensional, 3D: three-dimensional, PBO+: Perfect Bleach Office+, RW: red wine

any of the optical parameters ($p>0.05$). The only statistically significant difference for OB and PBO+, was observed for the calculated ΔE_{00} values of the RW groups for the changes between bleaching and staining ($p=0.000$). For intragroup comparisons of OB, the RW group showed significantly higher ΔE_{00} values than both the control and the TC groups ($p=0.000$). For ΔWI_D values, a significant difference was only observed between the control and the RW groups for OB ($p=0.032$). For intragroup comparisons of PBO+, there was no statistically significant difference between the specimens stained with different beverages ($p>0.05$).

The 2D and 3D images obtained by AFM are shown in Figures 1–6. The results of surface analysis are shown in Table 4. All of the medians calculated for the R_a values of each specimen were lower than 0.2 µm, which is the critical R_a value needed for biofilm adhesion. Positive R_{sk} values were observed only for those specimens immersed in DW. While the distribution curve of R_{ku} was platykurtoic ($R_{ku}<3$) for both of the DW specimens, it was leptokurtoic ($R_{ku}>3$) for the other four specimens.

DISCUSSION

New trends in the present decade relating to perceptions of beauty and esthetics have resulted in an increasing demand for dental bleaching applications. One of the main causes of dental discoloration is the frequent consumption of staining beverages.

In the present study, we aimed to compare the effects of two of the most common staining beverages on the full crown of the maxillary incisor and the efficacy of two different office bleaching agents. Additionally, we aimed to analyze the surface topography of the teeth

after bleaching applications to determine the possible formation of irregularities which can make the dental structures more prone to be stained after bleaching, and if the interactions with the dental hard tissues differs due to differences in the chromogenic molecules.

As light reaches dental tissues, a sequence of interactions, such as scattering, reflection and absorption, occur between the enamel and dentin which results in color perception.[17] By separating the enamel and the dentin, these interactions are eliminated which can cause differences in color perception. According to this, for a more realistic color analysis, we opted to prepare full crown samples of the maxillary incisors. As two local and most commonly consumed staining beverages are Turkish coffee and red wine in our country, we decided to study these with a distilled water control group.

The first and the second null hypotheses of this study were partially rejected according to the results of the color and whiteness difference measurements. At the end of the staining period, all the study groups showed color changes higher than the acceptability threshold (ΔE_{00}>1.8). The changes with respect to the control group may be defined by the increase in rehydration of the dental tissues. The highest changes were observed in the RW group where there was a significant difference only with the controls (p=0.001). Although the TC group showed higher changes than the DW group, there was no statistically significant difference between either the DW or the RW groups (p>0.05). There are studies[3,27,28] supporting these results. The staining mechanism of RW can be ascribed to the lower pH caused by its acidic content (maleic acid, tartaric acid, lactic acid, succinic acid, citric acid, acetic acid) which can cause erosion which may increase the penetration of the staining pigments.[3,29] Similar to RW, TC also has a lower pH than DW. In addition to having a lower pH, the staining mechanisms of TC and RW can be ascribed to the tannin molecule found in their structure. Tannin is a staining pigment that can chemically bond to the hydroxyapatite of enamel and dentin.[29,30]

The observed color and whiteness changes after bleaching were higher than the acceptability thresholds for all groups. This shows the efficacy of both of the bleaching agents. The third null hypothesis was partially rejected because there was only a significant difference observed for the RW groups with OB and PBO+ between the staining and bleaching measurements (p=0.000).

Lower ΔE_{00} values observed in the control groups of both bleaching agents were inconsistent with the results of another study.[31] Although there was no significant difference in the control groups (p=1.000), PBO+ showed higher color differences than OB. On the other hand, lower color changes were observed in the TC and RW groups after the application of PBO+. The whiteness difference values supported these results. It may be concluded that the higher concentration of hydrogen peroxide in OB and the erosion caused by the lower pH values of TC and RW increased the diffusion of hydrogen peroxide and so increased the effect of OB more than PBO+. For intragroup comparisons, no statistically significant difference was observed in the PBO+ groups, while higher changes were observed in the RW group of OB.

The light transmission ability of a material is described as translucency. A lot of factors such as the color, mineralization level, chemical structure, thickness, hydration level etc. of enamel and dentin can affect their translucency parameter. The first null hypothesis of the present study was partially accepted according to the results of the translucency difference measurements. All of the measured changes in the translucency parameters were higher than the perceptibility threshold but lower than the acceptability threshold. Additionally, no statistically significant difference was observed between the ΔTP_{00} values of the study groups for all of the measurement periods (p>0.05). These low translucency changes are consistent with the results of some other studies.[32,33] Ma et al.[16] showed more changes in the TP of enamel in their bleaching group. These results show that neither staining nor bleaching caused critical changes in the chemical structure of enamel or dentin. However, not knowing the exact reactions at the molecular level is a limitation for the present study.

The low pH of the staining solutions and the chemical reactions occurring due to the bleaching process can cause changes in the surface characteristics of dental tissues, which may also change the color perception. Additionally, a surface roughness of more than 0.2 µm can increase biofilm accumulation, which can cause a recurrence of discoloration in a short period of time. To observe surface topography, an atomic force microscope was used in the present study.

According to the AFM analysis, the fourth null hypothesis was rejected. Differences were observed in the surface topography and roughness of each specimen. For the TC groups, the PBO+ applied specimens showed higher surface roughness values. None of the median R_a values were higher than 0.2 µm, which can be interpreted as meaning that the use of office bleaching agents is safe and the risk of recurrence related with these agents is low. The low R_a values observed in the present study were consistent with the results of other studies.[31,34] These findings are also supported by the low ΔTP_{00} values, which are affected by the surface roughness.

R_{sk} is the examination of the profile symmetry regarding the mean line.[35] When R_{sk} was analyzed, only the DW groups showed positive skewness, which is a sign of high peaks or valleys filled in. R_{ku} describes the sharpness of the probability density of the profile.[35] While the distribution curve of R_{ku} was platykurtoic (R_{ku}<3) for both of the DW groups, it was leptokurtoic (R_{ku}>3) for the other four groups. A platykurtoic distribution shows relatively fewer high peaks and low valleys, while a leptokurtoic distribution shows relatively more high peaks and low valleys in the same surface area.

The results of surface analysis may be interpreted as meaning that staining solutions with lower pH cause more demineralization and destruction at the surface but the porosities formed will not be critical for plaque adhesion or the recurrence of discoloration. With regards to this, it should be kept in mind that according to the etiological factors of discoloration, there will be differences in surface topography after the reactions by the bleaching applications have occurred. It may be better to induce re-mineralization after bleaching, especially discoloration relating to beverages with lower pH such as RW and TC, to decrease the risk of the recurrence. On the other hand, as mentioned before, not knowing the chemical reactions at the molecular level is a limitation for the present study. There is also a need for the repetition of staining after bleaching to clarify such a conclusion.

CONCLUSION

The frequent consumption of Turkish coffee and red wine can cause discolorations due to changes in the dental structures owing to their low pH and the staining pigments such as tannin, which can easily

react with the hydroxyapatite found in dentin and enamel. Oxidation reactions by hydrogen peroxide found in bleaching agents can react with these pigments and result in a perception of a whiter color of the dental tissues. Changes in the superficial structure caused by acidic beverages may increase the penetration of hydrogen peroxide and so the efficiency of the bleaching. The surface topography analysis showed that there will be differences in the surface structure after bleaching related to the type of staining molecule. Surface roughness values showed that office bleaching can be a safe method for the treatment of discolorations with a high efficiency in color and whiteness reversal but that topographic changes should be kept in mind and it may be better to induce re-mineralization especially after exposure to solutions with lower pH to minimize the risk of the recurrence.

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MAIN POINTS

- Both Turkish coffee and red wine stained the dental tissues.
- The bleaching agent with a higher concentration of hydrogen peroxide showed more efficiency in color reversal.
- Staining or bleaching did not significantly affect the translucency and surface roughness of the dental tissues.
- The low pH of the staining solutions may have affected changes in the surface topography of the enamel after bleaching.

ETHICS

Ethics Committee Approval: This study was approved by the Committee for Ethics of Research of Near East University (decision number: YDU/2016/37-287, date: 05.05.2016).

Informed Consent: Obtained.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: İ.K., E.C.Y., Design: İ.K., E.C.Y., Data Collection and/or Processing: İ.K., E.C.Y., Analysis and/or Interpretation: İ.K., E.C.Y., Literature Search: İ.K., E.C.Y., Writing: İ.K., E.C.Y., Critical Reviews: İ.K., E.C.Y.

DISCLOSURES

Conflict of Interest: The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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