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THE EFFECTS OF DEHYDRATION ON COLOR CHANGE IN NATURAL TEETH CAUSED BY DENTAL PROCEDURES

Doğal Dişlerde Dental Prosedür Kaynakli Renk Değişiminde Dehidrasyonun Etkileri

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ABSTRACT

This study examines the effects of several clinical procedures that lead to dehydration on color change in natural teeth. CIE L*, a*, and b* color coordinates of maxillary incisors were measured using a spectrophotometer before and after the procedure at minute intervals of 10, 20, 30, and 1440 (24 hours). Test groups were as follows: 6 and 15 minutes of the open mouth under LED and halogen dental reflectors; control groups were evaluated in a dark environment for 6 and 15 minutes; maxillary impressions were taken with condensation and additional type impression materials. Wilcoxon signed-rank tests and Mann–Whitney U tests were used for two-group comparisons. The analyses were computed by the Friedman and Kruskal–Wallis H tests for the paired and independent groups. These tests were followed by Bonferroni posthoc corrections. Obtained color values indicate significant L* changes for all groups due to dehydration for 20 minutes after the procedure. Color changes (ΔE) were significant for 30 minutes for the perceptibility (1.2>ΔE) and 20 minutes for the acceptability threshold (2.7>ΔE). Results show that experimental protocols designed to mimic dental procedures that require mouth opening may cause temporary discoloration of natural teeth, which may cause failure during shade matching.

Keywords: Color, Dehydration, Operative dentistry, Prosthodontics, Tooth.

ÖZ

Bu çalışma, dehidrasyona yol açan çeşitli klinik prosedürlerin doğal dişlerdeki renk değişimi üzerindeki etkilerini incelemektedir. Üst kesici dişlerin CIE L*, a* ve b* renk koordinatları, işlem öncesi ve sonrası 10, 20, 30 ve 1440 (24 saat) dakikalık aralıklarla bir spektrofotometre kullanılarak ölçüldü. Test grupları şu şekildeydi: LED ve halojen dental reflektörler altında 6 ve 15 dakika açık ağız; kontrol grupları karanlık bir ortamda 6 ve 15 dakika süreyle değerlendirildi; maksiller ölçüler kondenzasyon ve ilave tip ölçü materyalleri ile alınmıştır. İki gruplu karşılaştırmalar için Wilcoxon işaretli sıra testleri ve Mann-Whitney U testleri kullanıldı. Analizler, eşleştirilmiş ve bağımsız gruplar için Friedman ve Kruskal-Wallis H testleri ile hesaplandı. Bu testleri Bonferroni posthoc düzeltmeleri izledi. Elde edilen renk değerleri, işlemden 20 dakika sonra dehidrasyona bağlı olarak tüm gruplar için önemli L* değişikliklerini göstermektedir. Renk değişiklikleri (ΔE), algılanabilirlik eşiği (1.2>ΔE) için 30 dakika ve kabul edilebilirlik eşiği (2.7>ΔE) için 20 dakika boyunca önemliydi. Sonuçlar, ağız açılmasını gerektiren diş prosedürlerini taklit etmek için tasarlanmış deneysel protokollerin, doğal dişlerde geçici renk değişimlerine ve renk eşleştirme sırasında başarısızlığa neden olabileceğini göstermektedir.

Anahtar kelimeler: Dehidrasyon, Diş, Operatif diş hekimliği, Protez, Renk.

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INTRODUCTION

The increasing importance that society places on aesthetic values directly affect the materials, techniques, and treatment protocols used in dentistry (Balcı, Tuncel & Eroğlu, 2013). Accordingly, aesthetic practices in dentistry are a progressive and evolving field of study. The color match between the restoration and the natural teeth is of great importance for the success of the treatment and patient satisfaction in dentistry. The mismatch was found to be the primary reason (89.3%) for patient dissatisfaction with the appearance of their teeth (Samorodnitzky-Naveh, Geiger & Levin, 2007).

Success in color matching depends on many variables such as lightning, and the clinician's age, gender, nutrition, medication, experience, and color vision deficiencies (if any) are well-documented subjective factors that affect the clinician's color perception. (Chu, Devigus, Mieleszko, 2004; Ochiai & Sato, 2005; Pohlen, Hawlina, Sober & Kopac, 2016). Studies have shown that dental spectrophotometers, on the other hand, are not affected by these subjective parameters and make more successful color matching in terms of repeatability and reliability (Igiel et al., 2017; Liberato et al., 2019).

Some studies have shown that dehydration in natural teeth causes different color values even if a dental spectrophotometer is used (Burki, Watkins, Wilson & Fenlon, 2013; Russel, Gulfraz & Moss, 2000; Suliman et al., 2019). These color differences are not among the subjective criteria mentioned above that cause an adverse effect on the color perception of the clinician (Chu et al., 2004; Ochiai et al., 2005; Pohlen et al., 2016).

This reversible color change can be attributed to the inter-prism spaces on the enamel surface. These spaces become filled with air instead of saliva, which changes the reflective properties of the surface (Burki et al., 2013; Suliman et al., 2019). Therefore, the scheduling of the shade selection procedure is a crucial step to achieve acceptable aesthetics (Suliman et al., 2019).

Natural teeth are inevitably dehydrated during various dental procedures. For an appropriate color measurement, it is essential to determine the rehydration time of the tooth according to the dental procedures that cause dehydration. This in vivo study aimed to observe the color changes of the maxillary central incisors that were dehydrated as a result of some dental procedures and to determine the time interval in which these teeth returned to their normal color after rehydration.

MATERIAL AND METHODS

The ethical conduct of this study was approved by the School of Medicine Ethics Committee, Süleyman Demirel University (18.01.2018/198644). The participants signed a written consent form following the Helsinki Declaration of the World Medical Association. This study included a total of eighty (80) student participants (38 females and 42 males) from the School of Dentistry, Süleyman Demirel University. Their ages ranged from 19 to 23 years, with a mean of 21.5 years.

The participating students' maxillary right central incisor teeth were intact, free of any restoration, free of any gingival inflammation, and had not undergone orthodontic therapy within the last 12 months. They were randomly divided into eight groups, and each group had ten participants (n=10).

Group 1 (L6): Participants' teeth were exposed to LED reflector light (Venus Plus-L LED 4.900K; Stern Weber, Imola, Italy) at a standard distance of 75 cm for 6 min.

Group 2 (L15): Participants' teeth were exposed to LED reflector light (Venus Plus-L LED 4.900K; Stern Weber, Imola, Italy) at a standard distance of 75 cm for 15 min.

Group 3 (H6): Participants' teeth were exposed to a halogen reflector light (edi dental lamp 5000K; Faro, Ornago, Italy) at a standard distance of 75 cm for 6 min.

Group 4 (H15): Participants' teeth were exposed to a halogen reflector light (edi dental lamp 5000K; Faro, Ornago, Italy) at a standard distance of 75 cm for 15 min.

Group 5 (C6): Participants were kept in the darkroom for 6 min with their mouths open.

Group 6 (C15): Participants were kept in the darkroom for 15 min with their mouths open.

Group 7 (C_Sil): Maxillary impressions of the participants' teeth were taken using a condensation type silicone impression material (Zetaplus; Zermack, Germany).

Group 8 (A_Sil): Maxillary impressions of the participants' teeth were taken using an additional type of silicone impression material (elite HD; Zermack, Germany).

Mouth retractors were used to keep the participants' mouths open, except for groups 7 (C_Sil) and 8 (A_Sil). Impression procedures were performed according to the manufacturing company's instructions.

A dental spectrophotometer (Vita Easyshade V; VITA, Bad Säckingen, Germany) was used to define tooth color and evaluate color changes. Participants brushed their teeth with the same brand of toothbrush (Oral B Complete; Proctor & Gamble, İstanbul, Turkey) with the same toothpaste (Colgate Total; Colgate-Palmolive, İstanbul, Turkey) before any procedures. Infection protection barriers were used for each participant. The spectrophotometer was

calibrated before each assessment using a calibration component. Measurements were performed from the facial centers (i.e., middle one-third) of intact maxillary right central incisor teeth. The probe of the equipment was placed with a 90-degree angle on the targeted area. Each measurement was repeated three times, and the average CIE L* a* b* values were recorded.

Spectrophotometric measurements were made immediately before and after the procedure and were repeated at 10, 20, and 30 minutes and 24 hours. Thus, based on six spectrophotometric measurements, data were obtained to evaluate color changes. The same researcher implemented all the assessments to avoid bias. The ΔE formula ($\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{½}$) was used to determine color changes (Balcı et al., 2013; Berns, 2000).

All the statistical tests were completed by non-parametric statistical methods since the sample sizes for all the groups were less than 15 (n=10). However, we checked and looked at the differences between the datasets via parametric counterparts and tabulated the mean and SD values of the L*, a* b*, and color difference values (ΔE). Wilcoxon signed-rank tests of a non-parametric statistical hypothesis test are used to compare two matched groups. Non–parametric Mann–Whitney U tests investigated the comparison of two different groups. The analyses for the two groups were computed by Friedman tests and Kruskal–Wallis H tests for the paired and independent groups, respectively. These tests were followed by Bonferroni posthoc corrections. All analyses were carried out at a 5% significance level ($\alpha = 0.05$). The statistical analysis was performed using a dedicated software package (SPSS 25 v2; Chicago, IL, USA).

RESULTS

The CIE L*a*b* color values were displayed as means and SDs in Tables 1–3. In the tables, ' 'Before' and 'after' values refer to the measurements taken immediately before and after the procedure. This process is defined as dehydration. Repeated measurements at 10, 20, and 30 minutes and 24 hours in the same tables are defined as rehydration. An increase in the L* values was monitored before and after the dental procedures implemented in this study (Table 1). This increase during the dehydration period was statistically significant for all groups ($p<0.001$, except for the L6 group: $p=0.001$). The L* values decreased during the rehydration period (10 min, 20 min, 30 min, and 24 h). Despite this decrease, the difference was statistically significant compared to the initial measurements for all groups at the 10-minute measurement. L15, A_Sil, and C_15 showed statistically significant L* values at 20 minutes ($p<0.05$).

Table 1. L* Values (Mean±SD) of the Groups According to the Time Variable.

L* Values						
	Dehydration		**Rehydration**			
	Before	**After**	**10 min**	**20 min**	**30 min**	**24 h**
L6	84.7 (±2.9)	88.1 (±2.6)*	87.4 (±2.6)*	86.6 (±2.7)	86.3 (±2.6)	86.6 (±2.9)
L15	85.5 (±1.1)	89.3 (±1.0)*	88.4 (±0.8)*	87.7 (±0.8)*	86.8 (±0.8)	85.6 (±1.1)
H6	84.4 (±2.3)	88.0 (±2.1)*	87.0 (±1.9)*	86.4 (±1.9)	85.7 (±2.1)	84.1 (±2.0)
H15	85.9 (±2.5)	90.1 (±1.9)*	88.7 (±1.7)*	87.6 (±1.7)	87.0 (±1.8)	85.8 (±2.3)
C_Sil	85.2 (±1.6)	88.4 (±1.8)*	87.8 (±1.7)*	87.1 (±1.6)	86.7 (±1.6)	85.9 (±1.4)
A_Sil	83.8 (±3.7)	87.5 (±3.7)*	86.7 (±3.9)*	85.9 (±3.9)*	85.3 (±3.9)	84.3 (±3.8)
C6	73.4 (±1.3)	76.6 (±0.4)*	76.1 (±1.4)*	75.2 (±1.8)	74.0 (±1.8)	73.3 (±1.3)
C15	82.2 (±6.5)	85.9 (±1.2)*	85.1 (±6.3)*	83.7 (±5.8)*	82.7 (±5.7)	82.3 (±6.3)

* Statistical Significance from the Baseline Measurement Shows the Comparison of Preliminary L* Values Of Each Group due to Time Intervals ($p<0.05$). No Statistical Significance Was Observed among the Other Groups.

During the dehydration and rehydration periods of the examined groups, there was no statistically significant change computed in the values of a* and b* (Tables 2–3).

Table 2. a* Values (Mean±SD) of the Groups According to the Time Variable.

a* Values						
	Dehydration		**Rehydration**			
	Before	**After**	**10 min**	**20 min**	**30 min**	**24 h**
L6	0.3±1.0	0.7±0.9	0.4±0.9	0.3±1.0	0.3±1.0	0.3±1.0
15	-0.9±0.8	-0.9±0.8	-0.8±0.9	0.9±0.8	-0.8±0.8	-0.9±0.8
H6	-0.2±0.9	-0.2±0.8	-0.2±0.8	0.1±0.9	-0.2±0.9	-0.3±0.9
H15	-0.6±1.1	-0.6±1.4	-0.7±1.2	0.6±1.1	-0.7±0.9	-0.6±1.1
C_Sil	-0.7±1.0	-0.8±0.9	-0.8±0.9	0.7±0.8	-0.7±0.9	-0.8±0.8
A_Sil	-0.3±1.3	-0.3±1.3	-0.3±1.2	0.3±1.3	-0.3±1.3	-0.3±1.3
C6	0.9±0.4	0.9±0.4	0.9±0.5	0.9±0.4	0.9±0.6	0.9±0.4
C15	-0.7±1.1	-0.7±1.2	-0.7±1.2	0.7±1.2	-0.7±1.2	-0.7±1.0

No Statistical Significance Was Observed among the Analyzed Groups ($p<0.05$).

Table 3. b* Values (mean±SD) of the Groups According to the Time Variable.

b* Values						
	Dehydration		**Rehydration**			
	Before	**After**	**10 min**	**20 min**	**30 min**	**24 h**
L6	18.7±2.4	18.6±2.5	18.8±2.2	18.6±2.4	18.7±2.5	18.6±2.4
L15	19.2±2.7	19.6±2.5	19.3±3.2	19.2±3.1	19.3±2.9	19.4±2.1
H6	22.2±4.0	22.2±3.7	22.6±4.5	22.3±3.8	22.6±3.1	22.4±3.7
H15	20.7±3.8	20.7±4.3	20.8±3.4	20.5±3.6	20.6±2.9	20.4±3.7
C_Sil	19.1±3.5	19.2±3.7	19.3±3.4	19.2±3.4	19.1±3.6	19.0±3.4
A_Sil	20.8±4.1	20.6±4.2	20.6±4.2	20.7±4.0	20.6±4.4	20.6±4.1
C6	21.5±2.2	21.4±2.0	22.0±3.0	21.4±2.6	21.3±2.6	21.3±2.2
C15	17.9±4.1	18.0±4.4	17.9±4.3	17.9±4.3	17.9±3.9	17.9±4.3

No Statistical Significance Was Observed Among the Analyzed Groups ($p<0.05$).

The color difference (ΔE) was calculated between the time intervals of before–after, before–10', before–20', before–30', and before–24h (Table 4).

The highest ΔE value, which defines the color change during dehydration (ΔE_T_0), was observed in the H15 group. During the dehydration procedure (ΔE_T_0), the ΔE value of the H15 group shows statistically significant differences from the other groups C6, C_Sil, and L6

(Tables 4–5). ΔE values for all calculated groups decreased in the rehydration process (Figure 1). There was no statistical difference when the color changes were evaluated between the groups at all time intervals.

Table 4. The Groups' Color Difference (ΔE) Values (Mean±SD) According to the Time Variable.

	ΔE_T$_0$'	**ΔE_T$_{10}$'**	**ΔE_T$_{20}$'**	**ΔE_T$_{30}$'**	**ΔE_T$_{24h}$**
L6	3.4±0.4^{a}	2.8±0.6	2.0±1.1	1.8±0.9	0.6±0.5
L15	4.0±0.6^{ab}	3.5±1.1	2.7±0.1	2.1±1.7	0.6±0.7
H6	3.6±0.6^{ab}	2.8±0.7	2.2±0.9	1.7±0.8	0.7±0.5
H15	4.5±0.6^{b}	3.4±0.8	2.2±0.5	2.0±1.0	0.6±0.3
C_Sil	3.3±1.2^{a}	2.7±1.1	2.0±1.2	1.9±1.2	0.8±0.9
A_Sil	3.8±0.6^{ab}	3.0±0.7	2.2±0.9	1.8±0.1	0.6±0.5
C6	3.4±0.5^{a}	3.1±0.6	2.1±0.9	1.8±0.9	0.5±0.4
C15	3.8±0.7^{ab}	3.6±1.6	2.1±1.6	1.9±1.2	0.5±0.5

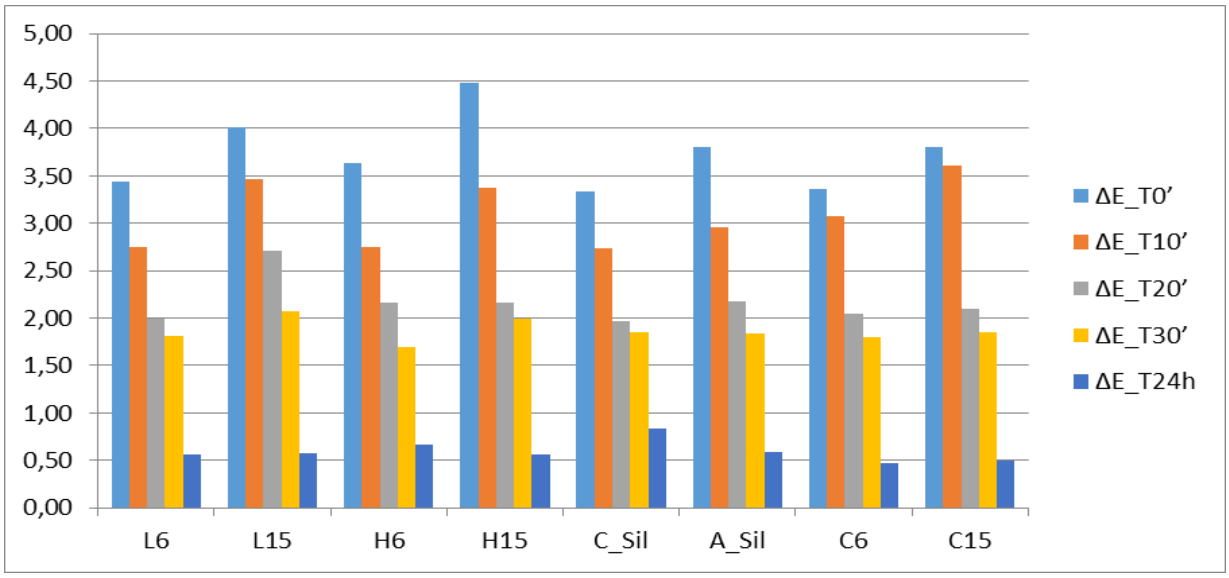

Figure 1. Bar Type Graph of the ΔE Values of the Experimental Groups Related to Time Intervals.

(Preliminary L*, a*, and the b* values before each procedure were taken as references to evaluate the ΔE values). Groups showing a statistical significance were indicated by superscript letters. Groups that did not show statistical significance were marked with the same letters. No statistical significance was observed among the other groups.

Table 5. Color Differences (ΔE) Were Computed at T_0 Levels Between Multiple Groups with Mean Ranks and P Values.

ΔE level at T_0 (m.), paired values	**Mean ranks**	**p**
C6	26.0	.009
H15	63.0	
L6	32.2	.041
H15	63.0	
C Sil	28.0	.019
H15		

The Kruskal–Wallis H Test Was Implemented for the Comparison of Multiple Groups (α=0.05).

DISCUSSION

Dental treatments generally require patients to keep their mouths open for varying periods. Although few, some in vivo studies have shown that short-term mouth opening causes discoloration of natural teeth due to dehydration (Burki et al., 2013; Russel et al., 2000; Suliman et al., 2019). The results of the present study support that this dehydration, which occurs in short-term dental procedures, may also cause discoloration of natural teeth.

The coherent conditions to clinical procedures were designed in this present study to provoke the dehydration of vital teeth. In order to determine the color values of natural teeth and make comparisons, the use of a dental spectrophotometer, which is a reproducible and reliable method, was preferred instead of visual color selection (Derdilopoulu, Zantner, Neumann & Kielbassa, 2007; Kielbassa, Beheim-Schwarzbach, Neumann, Nat & Zantner, 2009). In this way, tooth color assessment could be performed over measurable parameters.

Taking a maxillary or mandibular impression is a standard procedure in dental practice, and the effects of this procedure on the color perception of natural teeth have been studied (Russel et al., 2000). In the current study, we implemented two different impression materials with different chemical structures and polymerization methods (Shen, 2013).

Dental reflectors are an indispensable part of restorative procedures as they enable the practitioner to see the operational area. Conventional halogen lights, the light source used in these devices, are especially susceptible to heat generation during dental procedures. An advantage of LED-type reflectors is that they produce no heat (Rawls & Esquivel-Upshaw, 2013; Tarle et al., 2002). The researchers of this present study hypothesized that the heat generation from halogen-type dental reflectors accentuates the dehydration of vital teeth. For this reason, color change due to dehydration using two different types of reflectors with the potential to radiate heat were included in the study.

When the studies on the effects of dehydration on tooth color were assessed, it was observed that the implemented clinical procedures were limited, such as only rubber-dam application or impression taking (Burki et al., 2013; Russel et al., 2000; Suliman et al., 2019). Therefore, we aimed to enhance the clinical scenarios that can cause dehydration in the current study (L6, L15, H6, H15, C6, C15, C_Sil, and A_Sil).

When the color values of the teeth were evaluated, the L* values in all groups showed a statistically significant increase, which depended on the procedures applied, based on the examined data (Table 1). This increase is shown to be the result of the dehydration that is caused by these procedures (Burki et al., 2013; Russel et al., 2000; Suliman et al., 2019). Color

perception involves a light source, an object that reflects the light, and an observer (Berns, 2000). During the detection of tooth color, the human eye sees only the top layer of the tooth, which is termed enamel. The enamel has a transparent structure. Under a light source, part of the ambient light refracts and passes through the tooth, while some light is reflected from the surface of the enamel and reaches the observer's eye. Therefore, the perceived tooth color consists of the reflected color from the enamel surface and the underlying anatomic structure dentin, which is different (Dozic, Kleverlaan, Aartman & Feilzer, 2004). Under normal circumstances, saliva/water covers the enamel surface and the enamel prisms, and dehydration replaces this saliva/water with air (Brodbelt, O'Brien, Fan, Frazer-Dib & Yu, 1981). Due to the different refractive indices of air and saliva/water (1.00 and 1.33, respectively), the light refracts off each differently (Meng et al., 2009). Consequently, the enamel becomes more reflective as its translucency is reduced, and whiter tooth color is thus detected, masking the color of the dentin underneath (Burki et al., 2013; Fondriest, 2003; Suliman et al., 2019).

In this study, the L* values obtained in the second evaluation phase during the rehydration process (10 minutes after the procedure) were also statistically significant compared to the initial measurements. It is reported that inter-prism spaces need at least 15 minutes to fill with saliva/water again (Suliman et al., 2019). The findings of this study confirm that L* values do not return to their average values immediately after the rehydration phase. As seen in Table 1, the L* values detected at 30 minutes after the procedure show no statistically significant difference compared with the initial measurements. The L* parameter values showed similar behavior in in-vivo studies on the subject (Burki et al., 2013; Russel et al., 2000; Suliman et al., 2019). The other color parameters the a* and b* values measured in this study showed no statistically significant difference for any procedure or group (Tables 2–3). However, there are also studies reporting significant differences in a* and b* values due to dehydration (Burki et al., 2013; Suliman et al., 2019). In a similar study detecting the effect of dehydration on the color of natural teeth, no statistical differences for b* values and statistically significant differences for a* values were found (Meng et al., 2009). The reason for these different results observed in the studies may be related to the fact that the volunteers participating in the studies were not identical in terms of mean age and sample size.

Some researchers sought to determine the principal indicator of color change through a measurable value (i.e., ΔE) in perceptibility and acceptability limits (Douglas, Steinhauer & Gee, 2007; Paravina, Ontiveros & Powers 2004; Paravina, et al., 2015). The perceptibility threshold value was determined as 1.2 ΔE units and the acceptability threshold value as 2.7 ΔE units, based on half of the observers in their clinical research (Paravina, et al., 2015). These

thresholds were set as the clinical significance level in the current study. This study showed that dehydration caused by dental procedures resulted in the ΔE levels exceeding both perceptibility and acceptability of the threshold values (Table 4). As for perceptibility, all procedures induced the ΔE levels to exceed the threshold (ΔE>1.2) until 30 minutes after the procedure. Nonetheless, the measurements at 24 hours showed the ΔE levels to be less than the threshold values for perceptibility. Utilizing the acceptable values of the threshold (ΔE>2.7), the ΔE values of the experimental groups showed a similar increase after the procedures. In our case, the acceptable ΔE values were obtained at 20 minutes. The ΔE color changes of vital teeth in the current study show similar results to previous in vivo studies that analyzed the effects of dehydration procedures (Burki et al., 2013; Russel et al., 2000; Suliman et al., 2019).

One of the strengths of this study is the use of multiple groups that imitate dental procedures that lead to dehydration. However, since this study was based on volunteerism, the sample size in each group was limited to ten. Larger sample groups may produce statistically more reliable results. Rubber dam application also causes dehydration in natural teeth. Depending on the procedures (such as filling and endodontic treatment) to be applied to the tooth, the duration of the rubber dam in the mouth varies. It may not be correct to determine an exact time as the rubber dam application time and to imitate it with an in vivo scenario. Due to these reasons, our study could not determine a protocol imitating the rubber dam application. Besides, previous studies used 10 and 30 minute intervals for rubber-dam. The aim of our study was to observe the color changes that may occur even in short-term dental procedures.

CONCLUSIONS

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

- Short-time dental procedures that can lead to dehydration in natural teeth caused changes in color values.
- These color changes in natural teeth have exceeded the perceptible and acceptable limit values in aesthetic expectations.

For aesthetic results, shade measurement should be performed at the beginning of the appointment or a day after the appointment.

Ethics Approval and Consent to Participate

The ethical conduct of this study was approved by the School of Medicine Ethics Committee, Süleyman Demirel University (18.01.2018 / 198644). The participants signed a written consent form following the Helsinki Declaration of the World Medical Association.

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