Selcuk Dental Journal 12/1 (Nisan 2025): 26-31

Research / Araştırma Makalesi

Effect Of Preheating On Color Stability Of Two Different Nanohybrid Composite Resins

Ön Isıtma İşleminin İki Farklı Nanohibrit Kompozit Rezinin Renk Stabilitesine Etkisi

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ABSTRACT

Backround: Preheating of composite resins has become widespread in recent years in order to improve the properties of the material. The aim of the study was to evaluate the effect of preheating on the color stability of two different composite resins.

Methods: In this study, 48 composite discs (2*8mm) were used, 24 of which were universal nanohybrid composite (Clearfil Majesty Estetic (CME), Kuraray, Japan) and 24 posterior nanohybrid composite (Clearfil Majesty Posterior (CMP), Kuraray, Japan). Half of the samples in each group were prepared by preheating at room temperature and the other half at 55°C (n:12). After the curing process, the samples were kept in distilled water at 37°C for 24 hours. Color was initially measured with a spectrophotometer after soaking in a coffee solution for 1 week and 1 month. Data were analyzed via SPSS 22.0 Two-Way Anova, Post-Hoc Tukey and Paired Samples T test.

Results: After storage in coffee solution, CME became significantly less discolored than CMP ($p<0.05$). There was a slight increase in coloration in the preheating groups of composite resins, but it wasn't statistically significant ($p>0.05$). The difference between 1-week and 1-month color changes in both composite groups was statistically significant ($p<0.001$).

Conclusions: Within the limitations of this study, preheating didn't have a positive effect on the color stability of the composite resins. The preheating method, which has become more common in recent years to improve the mechanical properties of composite resins, may not provide any benefit in the color stability of composite resins.

Keywords: Color Stability, Composite, Discoloration, Preheating, Spectrophotometer

ÖZ

Amaç: Materyalerin özelliklerini geliştirmek amacıyla kompozit rezinlerin ön ısıtılması son yıllarda yaygınlaşmaktadır. Çalışmanın amacı, ön ısıtmanın iki farklı kompozit rezinin renk stabilitesi üzerindeki etkisini değerlendirmektir.

Yöntemler: Bu çalışmada 24 universal nanohibrit kompozit (Clearfil Majesty Estetic (CME), Kuraray, Japonya) ve 24 posterior nanohibrit kompozit (Clearfil Majesty Posterior (CMP), Kuraray, Japonya) olmak üzere 48 kompozit disk (2*8mm) kullanıldı. Her gruptaki örneklerin yarısı oda sıcaklığında, diğer yarısı 55°C'de ön ısıtma uygulanıp hazırlandı (n:12). Polimerizasyonun ardından numuneler 37°C'de distile suda 24 saat bekletildi. Renk başlangıçta ve birinci hafta ile birinci ayda bir kahve solüsyonunda bekletmenin ardından bir spektrofotometre ile ölçüldü. Veriler SPSS 22.0 Two-Way Anova, Post-Hoc Tukey ve Paired Samples T testi aracılığıyla analiz edildi.

Bulgular: Kahve çözeltisinde beklemenin ardından CME, CMP'ye göre önemli ölçüde daha az renklendi ($p<0.05$). Kompozit rezinlerin ön ısıtma gruplarında renklenmede hafif bir artış oldu ancak istatistiksel olarak anlamlı değildi ($p>0.05$). Her iki kompozit grubunda 1 haftalık ve 1 aylık renk değişiklikleri arasındaki fark istatistiksel olarak anlamlıydı ($p<0.001$).

Sonuç: Bu çalışmanın sınırlamaları dahilinde, ön ısıtmanın kompozit rezinlerin renk stabilitesi üzerinde olumlu bir etkisi olmamıştır. Kompozit rezinlerin mekanik özelliklerini geliştirmek amacıyla son yıllarda kullanımı yaygınlaşan ön ısıtma yöntemi, renk stabilitesi açısından herhangi bir fayda sağlayamayabilir.

Anahtar Kelimeler: Kompozit, Ön Isıtma, Renklenme, Renk Stabilitesi, Spektrofotometre

INTRODUCTION

Composite resins, which are among the restorative materials frequently used in dentistry in recent years, offer advantages to clinicians such as bonding to enamel and dentin, color and mechanical properties similar to natural teeth, easy applicability, and relatively low cost.[1] However, insufficient polymerisation, volumetric shrinkage which always accompanies the polymerization reaction of composite resins containing dimethylpropionate groups to a certain degree (2.7%-7.1%), bonding failure, microcracks in the material and secondary caries, and postoperative sensitivity due to gaps between the composite resin and the cavity wall remain important limitations.[2] In addition, color change in the composite material negatively affects the long-term success of the restorations.[3,4]

The change in composite resin color is a multifactorial phenomenon of endogenous or exogenous origin. Exogenous factors include the absorption of coloring materials from external sources related to the patient's eating and drinking habits, oral hygiene habits, and smoking habits. Meanwhile, endogenous factors include the chemical composition of the resin matrix, the amount, size, and distribution of filler particles, and changes in the interface between the matrix.[3,5]

The color change of the resin matrix is related to the degree of conversion, physicochemical properties and hydrophilicity of the matrix.[6,7] The polymerization reaction of light-cured composite resin occurs through the decomposition of the photosensitizer into free radicals. Free radicals become active centers and interact with monomers. The degree of monomer conversion affects the chemical stability of the material.[8,9] Unconverted double carbon bonds can make the material more susceptible to degradation[10], leading to the release of products such as formaldehyde and methacrylic acid and decreased color stability.[11]

In addition to the past and present developments in the composition of composite resins, alternative strategies such as preheating the material at a certain temperature have been used in recent years to expand the applicability of composite resin. Various studies have been conducted on the effects of preheating on composite resins.[12-16] Preheating of conventional composite resin can improve physicochemical properties by increasing the degree of conversion of monomers and cross-linking in polymer formation.[17,18]

In this method, the material is heated at temperatures ranging from 30°C to 68°C before being placed in the cavity. This preheating of the composite results in increased molecular mobility, higher degree of polymerization, reduction of residual monomers, and increased fluidity.[19]

Studies have often focused on the changes in the mechanical properties of composite resins caused by preheating. However, studies on the changes caused by this method in the optical properties of composite resins are limited, and the results are contradictory, such as having a positive or negative effect on coloration[20] or no effect being observed.[21] This study aimed to evaluate the effect of preheating on the color stability of composite resins on two different composite resins.

The first null hypothesis is that color stability would not be different

Gönderilme Tarihi/Received: 7 Mart, 2024
Kabul Tarihi/Accepted: 25 Nisan, 2024
Yayınlanma Tarihi/Published: 21 Nisan, 2025
Atıf Bilgisi/Cite this article as: Aktuğ Karademir S, Atasoy S, Akarsu S. Effect Of Preheating On Color Stability Of Two Different Nanohybrid Composite Resins. Selcuk Dent J 2025;12(1): 26-31 Doi: 10.15311/ selcukdentj.1448606

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Doi: 10.15311/ selcukdentj.1448606

between two composites with different components (universal/posterior) after soaking in coffee solutions. The second null hypothesis is that preheating would make no difference in the coloration of composite resins.

MATERIAL AND METHOD

Sample preparation

In this in vitro study, nanohybrid universal composite (Group 1: Clearfil Majesty Esthetic (A2), Kuraray, Okayama, Japan) and nanohybrid posterior composite (Group 2: Clearfil Majesty Posterior (A2), Kuraray, Okayama, Japan) were used. In total, 48 disc-shaped samples, 24 from each composite group, were prepared using Teflon molds with a depth of 2 mm and a diameter of 8 mm. The properties of the materials used in the study are listed in **Table 1**.

Table 1. Restorative Materials Used in the Study

Material	Type	Contents	Filler Ratio	Manufacturer/Lot
Clearfil Majesty Esthetic (CME)	Nanohybrid	• Silanated barium glass • Pre-polymerized organic filler • Bisphenol A diglycidyl methacrylate (Bis-GMA) • Hydrophobic aromatic dimethacrylate • dl-camphorquinone	40% Vol Particle size: 0.37µm-1.5µm	Kuraray, Tokyo, Japan LOT: 310241
Clearfil Majesty Posterior (CMP)	Nanohybrid	• Silanized glass ceramics • Surface treated aluminum oxide filler • Bisphenol A diglycidyl methacrylate (Bis-GMA) • Triethyleneglycol dimethacrylate (TEGDMA) • Hydrophobic aromatic dimethacrylate • dl-camphorquinone	82% VOL Particle size: 0.02µm-7.9µm	Kuraray, Tokyo, Japan LOT: 7F0096

The samples were divided into two groups according to the preparation temperature (n:12) as follows: Group 1a, Clearfil Majesty Esthetic (CME) 55˚C; Group 1b, CME at room temperature; Group 2a, Clearfil Majesty Posterior (CMP) 55˚C; and Group 2b, CMP at room temperature.

A composite heater (Micerium Ena Heat, Avegno, Italy) was used to heat the composite resins before polymerization, and the samples were heated to 55˚C before polymerization. Considering the temperature loss of the composite material during manipulation, the highest temperature allowed by the device was preferred. In order to prevent heat dissipation, the composite was removed from the heater in the preheating groups and placed in the cavity within a maximum of 10 seconds.

The samples were prepared on a glass coverslip with mylar strips on the upper and lower surfaces. Pressure was applied to the glass slide from the upper surface as much as the molds allowed in order to obtain a smooth surface. The samples were polymerized with an LED light device (Elipar S10, 3M, Seefeld, Germany) for 20 s at a right angle, with the tip of the device in contact with the glass. A radiometer was used to monitor light intensity. The room temperature was kept at 25˚C via air conditioning. Controls were made with a mercury thermometer.

Aluminum oxide disks (Soflex, 3M, USA) were used in the finishing and polishing processes of the samples. The disks were refreshed at each sample change. The polymerization was completed by keeping the samples, whose lower surfaces were marked with a bur, in distilled water at 37˚C for 24 hours. The samples were then dried with moisture-absorbing paper.

Storage in colorant solution

3.6gr of coffee (Nescafe Gold) prepared and cooled in 300 ml of boiled water was used as the coloring agent. The samples were fixed to a base plate wax in accordance with the order in the initial color measurement and immersed in the coffee solution. During the experimental period, the solution was renewed daily and each time the samples were washed under running water for 1 minute to prevent ponding. Storage in coffee was repeated for 7 days then the process continued up to 28 days.

Color measurement

Color measurements were carried out by the same operator on a standard white background under constant laboratory lighting at the beginning (t0), after 7 days (t1) and 28 days (t2) of coffee storage. At each of the t0, t1 and t2 measurements, L*, a* and b* values were recorded and averaged for three color measurements of each sample using a spectrophotometer ((Vita Easyshade V, Vita Zahnfabrik, Germany). Data were interpreted with the CIE L*a*b* system. While L* refers to the shade from black (0) to white (100). The a* indicates chromaticity from red (+80a*) to green (−80a*). The b* represents chromaticity from yellow (+80b*) to blue (−80b). Color differences between measurements at different times from the beginning were expressed as ΔE. The color change was calculated with the following formula.[7]

$\Delta E= [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

Statistical analysis

The Shapiro-Wilk test was used to determine whether the data were normally distrubuted, and it was observed that the data was normally distributed ($p>0.05$). Data were analyzed at 95% significance level using IBM SPSS (22.0) (IBM-SPSS Inc. Chicago, Illinois, USA). Differences between groups were evaluated by two-way analysis of variance (ANOVA) and post-hoc Tukey test for multiple comparisons of groups. Paired sample t test was used to examine color changes between times t1 and t2.

RESULTS

After soaking in coffee solution, both composite resins demonstrated color change at varying rates. When the color change (ΔE) data between the groups was examined after 1 week of storage in coffee, the least color change was observed in CME at room temperature [Group 1b (3.52±0.40], while the highest color change was observed in CMP at room temperature [Group 2b (8.85±0.67]. Color change data for the groups are shown in **figure 1**.

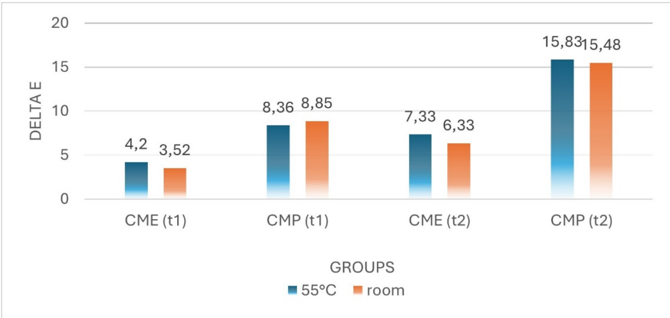

Figure 1. Color change in composites at both temperatures for times t1 and t2

When the color change data in the first week was examined, the effect of composite type on color change was significant ($p<0.001$), while the effect of temperature was not significant ($p =0.718$). The composite-temperature interaction was statistically significant ($p=0.027$). In the double examination of the ΔE values between the groups, the difference between group 1a/group 1b ($p=0.255$) and group 2a/2b ($p=0.533$) was insignificant, and the difference between the other groups was significant ($p<0.05$). The mean ΔE values, standard deviations, and p values for 1-week storage in coffee solution of both composite resins applied at two different temperatures are listed in **Table 2.**

Table 2. Color change data for the groups in the first week (t1)

Composite	Temperature	n	Mean ± SD
CME (Group1)	55 °C (a)	12	4.20±0.71[A]
	Room (b)	12	3.52±0.40[A]
CMP (Group 2)	55 °C (a)	12	8.36 ±1.41[B]
	Room (b)	12	8.85±0.67[B]

p value/ composite: <0.001, temperature: 0.718, composite*temperature: 0.027**
*Mean with different letters in the same column indicate statistically significant difference, *: significant (p < 0.05).*

The lowest color change of 1-month-old coffee during storage was observed in CME at room temperature [Group 1b (6.33±1.19)], whereas the highest color change was observed in CMP at 55˚C [Group 2a (15.83±) 1.88)].

According to the color change data in the first month, the effect of composite type on color change was significant ($p<0.001$), while the effect of temperature was not significant ($p=0.068$). The composite-temperature interaction was not statistically significant ($p=0.385$). In the double examination of the ΔE values between the groups, the difference between group 1a/group 1b ($p=0.226$) and group 2a/2b ($p=0.896$) was insignificant, and the difference between the other groups was significant ($p<0.05$).The mean ΔE values, standard deviations, and p values for 1-month storage in coffee solution of both composite resins applied at two different temperatures are listed in **Table 3**.

Table 3. Color change data for the groups in the first month (t2)

Composite	Temperature	n	Mean ± SD
CME (Group 1)	55°C (a)	12	$7,33 \pm 0,55^{A}$
	Room (b)	12	$6,33 \pm 1,19^{A}$
CMP (Group 2)	55°C (a)	12	$15,83 \pm 1,88^{B}$
	Room (b)	12	$15,48 \pm 1,01^{B}$

p value/ composite: <0.001, temperature: 0.068, composite*temperature: 0.385*
*Mean with different letters in the same column indicate statistically significant difference, *: significant (p < 0.05).*

When the difference between times was examined, the difference between 1-week (t1) and 1-month (t2) color changes for all groups was statistically significant ($p<0.001$). The minimum, maximum, average ΔE values, standard deviations and p values of both composites applied at two different temperatures between times t1 and t2 are listed in **Table 4**. The increase in color change over time is shown in **figure 2**.

Table 4. Statistical analysis data of the color change difference between t2 and t1 times

Paired Samples Test					
Composite	Temperature	n	Time	Mean	p
CME (Group1)	55 °C (1a)	12	t2– t1	3.13±0.57	<0.001
	Room (1b)	12	t2-t1	2.81±1.11	<0.001
CMP (Group 2)	55 °C (2a)	12	t2-t1	7.47±1.17	<0.001
	Room (2b)	12	t2-t1	6.62±1.21	<0.001

Statistical significance p<0.05

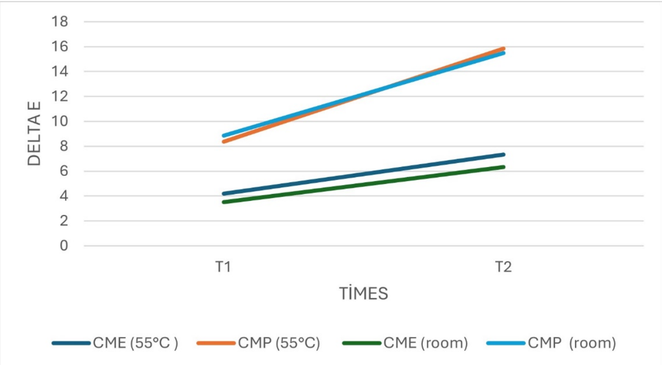

Figure 2. Increasing color change over time (t2-t1) in group

DISCUSSION

The first null hypothesis tested in this study was rejected as soaking in CME coffee solutions demonstrated significantly less color change. In the results of this study, preheating slightly increased the color change in both composite resins, but this increase was not statistically significant. Therefore, the second null hypothesis was accepted.

Significant differences in preheating device, heating time, and temperature have been reported in previous studies.[22] In the preheating method, devices such as Calset, Ena Hat, and Hot Set are more popular and reliable than keeping it in a hot water bath. Preheating temperature varies between 30˚C and 68˚C, and duration varies between 5 and 15 min.[22] Previous studies have reported that after pre-heating the composite resin, the temperature drops rapidly during application, and the working time is 10–15 s.[23] In this study, a composite heater (Micerium Ena Heat, Avegno, Italy), which is a more reliable method, was used instead of a water bath. To minimize heat loss during placement, the samples were heated to the highest possible temperature (55˚C) for 15 min and prepared with a working time of 10 s.

In most studies comparing coloration in different solutions, the highest coloration was observed in coffee after storage.[24,25] In this study, coffee-coloring solution was preferred in order to examine the results more clearly. Color was measured on days 7 and 30 with the VITA Easy Shade V spectrophotometer (Vita Zahnfabrik, Germany), which provides objective and reliable results owing to LED technology independent of ambient light. It has been reported that an average of 2-3 cups of coffee are drunk per day and the average drinking time is 15 minutes.[26] Therefore, approximately 30 months of coffee consumption was simulated with 30 days of coffee storage.

The color stability of composite resins is mainly related to the polymerization level as well as the resin matrix of the material, type, size, and shape of inorganic filler particles.[27] The resin matrix absorbs water to compensate for polymerization shrinkage due to the hydrolytic stability of the material.[28,29] This weakness in stability causes discoloration owing to poor bonding of the material to the resin-filler interface, deterioration of silanisation, and decrease in the physical properties of the material.[24,29] It has been reported that composites containing higher concentrations of triethyleneglycol dimethacrylate (TEGDMA) in the resin matrix are more prone to discoloration than those containing higher concentrations of urethane dimethacrylate.[30-33] With these monomers, the resin matrix becomes more hydrophilic and the absorption of water and other liquids increases, resulting in a color change in the material.[30,34,35] In this study, the least color change was observed in CME, which is a nanohybrid composite, on both the 7th (3.52±0.40) and 30th days (6.33±1.19). CMP was significantly more colored than CME in both time periods. These results can be associated with the TEGDMA content in the resin matrix of CMP, unlike CME, and its larger inorganic particle size compared to CME.

In the study of Tekçe N. et al., where they examined the surface roughness of CME and CMP with an atomic force microscope, CMP demonstrated significantly more surface roughness than CME after 1 year of storage in water.[36] Considering the importance of maintaining surface smoothness in the color stability of the material, these results support the results of our study.

Recent studies have focused on heating composite resin to improve its properties.[12,37,38] Although heating the composite resin before photopolymerisation reduces the viscosity, it can improve its mechanical properties, including an increase in the conversion rate and surface hardness.[14,16] However, the effect of preheating on the color stability of composite resin remains controversial. Previous studies have reported that preheating the composite resin achieves a higher degree of conversion by increasing the mobility of radicals.[13,39] However, whether increased conversion affects the color stability of the material is debatable. Mundim et al. have reported that although pH increased the degree of transformation, it had no effect on color stability.[21]

The composition of composite resin affects how the material responds to preheating because thermal conductivity can be affected by the filler content as well as the distribution of the filler in the composite resin and the particle type, shape, and size.[40,41] Although less thermally conductive than the filler content, the organic matrix may be more responsive to preheating. In our study, preheating increased the color change of CME on the 7th day and both CMP and CME on the 30th day, but this increase was not statistically significant ($p>0.05$). In the study of Abdulmajeed AA et al. in which they examined the wear and color stability of conventional and bulk fill composites with preheating, preheating increased the coloration of Filtek One Bulk Fill Restorative in coffee solution, although this increase was not significant.[42] In the same study, preheating slightly decreased the coloration of Filtek Supreme Ultra, although this decrease was not statistically significant. These results confirm that the effect of preheating is affected by the composite resin composition.

In the study of Alizadeh Oskoee P et al., where they examined the effectiveness of preheating on the surface roughness and coloration of composite resins in silorane-based composite resin, the preheating process increased color change compared to room temperature, and this increase was not statistically significant. In the same study, preheating significantly increased the surface roughness of composite resins.[7] Consistent with the results of our study, this increase in the coloration of the preheated groups, the weakened covalent bond between the quartz particles and resin matrix caused by heating may cause further separation of the filler particles[44] and thus, the increase in roughness.

In the studies of Kahnamouei MA et al., 40 rounds of repeated preheating significantly increased the coloration of the composites used.[43] In the results of our study, the coloration increase in the preheated groups was not statistically significant, although the preheating process was applied once. Considering that the composite tubes are used repeatedly under clinical conditions, the effect of preheating on the color stability of the composite resin is worrying.

In the study of Farideh Darabi et al., in which they evaluated the effectiveness of preheating on coloration in tea, coffee, and distilled water, preheating significantly decreased the coloration in coffee samples, whereas no significant effect was observed in samples stored in tea. In distilled water, although coloration increased in the preheating group, this increase was not statistically significant.[44] Although preheating increases the degree of polymerization, its effectiveness on the resin matrix, weakened covalent bonds and particle breakage may make the material prone to water absorption and therefore, coloration.[43] Owing to the different results in different solutions, concluding that preheating is a useful method on coloration may be difficult.

The most recently accepted threshold values for tooth-colored materials are reported as ≥1.2 for detectability and <2.7 for acceptability.[45] In this study, all samples demonstrated color change that was detectable to the human eye and clinically unacceptable ($\Delta E>2.7$). Although continuous immersion of the composite samples applied in our study in coffee solution for 7 days and 30 days is insufficient to simulate the washing effect of saliva in clinical conditions, this method has been used previously in vitro.[46]

In fact, continuous immersion can be interpreted as an accelerated method of dyeing materials. The immersion period used in this study corresponds to a significantly longer period (approximately 30 months) in clinical conditions. In this study, coloration increased significantly with time. These results are consistent with those of other studies that also evaluated intertemporally.[47,48] An important limitation in our study was that the colors of the samples were not measured after coloring them in coffee and then repeating their polishing. Zajkani et al. They reported that the color change of composite resins colored in coffee and tea decreases after repolishing. [26] Additionally, in vivo conditions, the color change of the materials is less due to the washing effect of saliva and the oral hygiene of the patient. [49, 50] Therefore, clinical studies are needed to evaluate the color stability of preheated composite resins following colorant solution.

CONCLUSION

Within the limitations of this in vitro study, preheating did not have a significant adverse effect on color stability. However, under clinical conditions, repeated preheating of composite tubes may alter the results. The results need to be supported by in vivo studies under clinical conditions. Patients should be informed that resin-based materials may become discolored with coloring solutions such as coffee.

Author Contribution

The idea and hypothesis of the article, experimental design and contribution to the draft were provided by Sultan Aktuğ Karademir, Samet Atasoy, Serdar Akarsu. Statistical analysis and writing of the article belong to Sultan Aktuğ Karademir.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

*Bu makale Türk Diş hekimleri Birliği (TDB) 27. Uluslararası Dişhekimliği Kongresinde sözlü olarak sunulan ancak tam metni yayınlanmayan "The Effect of Preheating of Composite Resins on Color Stability" adlı tebliğin içeriği geliştirilerek ve kısmen değiştirilerek üretilmiş halidir.

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

This article is the version of the presentation named "The Effect of Preheating of Composite Resins on Color Stability", which was presented orally at the 27th International Dentistry Congress of the Turkish Dental Association (TDB), but whose full text was not published, by improving and partially changing the content.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

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Finansman / Grant Support

Yazarlar bu çalışma için finansal destek almadığını beyan etmiştir. | The authors declared that this study has received no financial support.

Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın tasarlanması / Design of Study: SAK (%50) SAt (%25) SA (%25)
Verilerin toplanması / Data Acquisition: SAK (%60) SAt (%20) SA (%20)
Veri Analizi / Data Analysis: SAK (%100)
Makalenin Yazımı / Writing up: SAK (%60) SAt (%20) SA (%20)
Makale Gönderimi ve Revizyonu / Submission and Revision: SAK (%60) SAt (%30) SA (%10)

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