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Investigation of Various Finishing/Polishing Procedures on Color Stability of Composite Resins

Farklı Bitim/Polisaj Sistemlerinin Rezin Kompozitlerin Renklenmesi Üzerine Etkisinin Değerlendirilmesi

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Abstract

Aim The objective of this study was to assess the impact of various finishing and polishing systems on the color stability of composite resins treated with coffee.

Material and Method Fifty samples of each of nanohybrid and supra-nanohybrid composite resin materials were prepared and each material was randomly divided into 5 groups (n=10): Group 1: Control group (mylar strip), Group 2: One Gloss (one step), Group 3: One Gloss + polishing paste, Group 4: Soflex disk (multistep), Group 5: Soflex disk + polishing paste. The samples were colored in coffee solution for 144 hours to simulate six months of coffee consumption after polishing. The color of the samples before-after staining was measured with a spectrophotometer and ΔE00 values were calculated.

Results Material, polishing type and the interaction of these two parameters had a statistical effect on the color change values ($p < 0.001$). The ΔE00 values of supra-nanohybrid composite resin were higher than nanohybrid. Both materials exhibited color change above the thresholds of clinical perceptibility (PT> 0.8) and acceptability (AT> 1.8). In terms of polishing types, the highest ΔE00 was found in the control group and the lowest in the disk group. Th e additionally applied polishing paste caused a non-signifi cant decrease in the color change of the one-step polishing system ($p < 0.05$) and a statistically signifi cant increase in the multi-step polishing system ($p > 0.05$).

Conclusion Considering the limitations of the study, it can be concluded that the use of multi-step discs is more advantageous in preventing discoloration of composite resins.

Keywords Color stability, composite resin, finishing and polishing

Özet

Amaç *Çalışmanın amacı; farklı bitim/polisaj sistemlerinin kahve ile renklendirilen kompozit rezinlerin renk stabilitesi üzerine etkilerinin değerlendirilmesidir.*

Gereç ve Yöntem *Nanohibrit ve supra-nanohibrit kompozit rezin materyallerinin her birinden 50 adet numune hazırlandı ve her materyal rastgele beş gruba (n=10) ayrıldı: Grup 1: Kontrol grubu (mylar strip), Grup 2: One Gloss (tek aşama), Grup 3: One Gloss + Polisaj patı, Grup 4: Soflex disk (çok aşama), Grup 5: Soflex disk + Polisaj patı. Numuneler, cila sonrası altı aylık kahve tüketimini taklit etmek amacıyla 144 saat boyunca kahve çözeltisinde renklendirildi. Spektrofotometre cihazı ile renklendirme öncesi/ sonrası numunelerin rengi ölçülüp ΔE00 değerleri hesaplandı.*

Bulgular *Malzeme, cila tipi ve bu iki parametrenin etkileşimi renk değişim değerlerine istatistiksel olarak etkili olduğu görüldü ($p<0,001$). Supra-nanohibrit kompozit rezinin ΔE00 değerleri, nanohibrit kompozit rezinden yüksekti. Her iki materyal de klinik olarak algılanabilirlik (PT> 0,8) ve kabul edilebilirlik (AT>1,8) eşik değerlerinin üzerinde renk değişimi sergiledi. Polisaj türleri bakımından, en yüksek ΔE00 kontrol grubunda, en düşük değer ise yalnızca disk uygulanan grupta bulundu. İlave olarak uygulanan polisaj patı, tek aşamalı polisaj sistemin renk değişiminde anlamlı olmayan bir azalışa ($p< 0,05$), çok aşamalı polisaj sisteminde ise istatistiksel olarak anlamlı bir artışa neden oldu ($p> 0,05$).*

Sonuç *Çalışmanın limitasyonları göz önünde bulundurulduğunda, çok aşamalı disk kullanımının kompozit rezinlerde oluşan renklenmeyi önlemede daha avantajlı olduğu değerlendirilebilir.*

Anahtar Kelimeler *Renk stabilitesi, kompozit rezin, bitim ve cila*

INTRODUCTION

In contemporary dental practice, composite resins have gained widespread acceptance for the restoration of both anterior and posterior dental structures, owing to their enhanced physical characteristics and esthetic qualities. Unfinished and unpolished restoration surfaces cause plaque retention, caries, surface discoloration and inflammation in the surrounding soft tissues.[1] In addition, the finishing and polishing step is also important for the removal of the oxygen-inhibition layer formed as a result of the reaction of free radicals with oxygen in the air during polymerization in the top layer of the composite resin.[2]

Finishing is performed to create the ideal anatomical form of the tooth, to prevent fracture of the restoration and to provide the patient with the correct chewing function; polishing is performed to make the restoration look smoother, brighter and more esthetic.[1] This can be done in a one-step or multi-step.[3] In addition to finishing and polishing, polishing paste can also be applied to composite resins.[4] The abrasive particles of the polishing system used should be harder than the filler particles of the composite resin to be contacted. Otherwise, the polishing material will not be able to remove the filler particles, which are an area suitable for coloration on the surface, but only the soft resin matrix.[5]

The structure and organic monomer content of the composite resins have a direct impact on the smoothness and staining susceptibility of the surface.[6] The organic phase of composite resins; low viscosity triethylene glycol dimethacrylate (TEGDMA) co-monomer, high viscosity bisphenol glycidyl methacrylate (Bis-GMA) monomer and urethane dimethacrylate (UDMA) monomer with high adhesion color stability, ethoxy bisphenol A-dimethacrylate (BisEMA), decanediol dimethacrylate (DDDMA), urethane tetramethacrylate (UTMA) and bisphenol methacryloxy polyethonoxy phenylpropane (Bis-MEPP).[7]

The resin matrix and filler particles have different sizes and hardnesses, resulting in different polishability properties.[8] Nanofill composite resins consist of nanomers and nanoclusters obtained by nanotechnological methods in the range of 0,1-100 nanometers (nm), while supra-nano composite resins have 200 nm spherical particles with a wavelength lower than the wavelength of visible light.[9,10] Nano composites have many advantages such as low polymerization shrinkage, high mechanical properties, improved optical properties, high wear resistance and polishability.[11] The maintenance of color stability in dental restorative materials constitutes a significant determinant influencing the overall success of dental restorations. The color change in the structure of composite resins is intrinsic coloration, while the coloration caused by contamination due to external factors is extrinsic coloration. Color changes are observed in composite resins in relation to water absorption, degree of polymerization conversion, surface roughness of the restoration and diet.[12] Many studies have investigated the changes in composite resin materials caused by dark colored beverages such as tea, red wine and coffee.[13-15]

Within the existing literature, numerous investigations have delved into scrutinizing the influence of diverse polishing systems on the color stability of composite resins.[1,16,17] However, there are very few studies on the effectiveness of polishing pastes used in addition to different polishing systems.[18,19] The present study is the first in the literature to examine the effectiveness of a polishing paste used in addition to both one-step and multi-step polishing systems. The objective is to assess the impact of distinct finishing/polishing systems on the color stability of nano and supra-nanohybrid composite resins, specifically those subjected to coffee-induced discoloration. The null hypotheses in this study were; (1) composite resins with different fillers do not affect color change and (2) polishing paste used in addition to polishing systems do not affect color change.

MATERIALS and METHODS

In the present study, the composite resins containing filler particles in two different sizes, nanohybrid (G-ænial Posterior, GC, Tokyo, Japan) and supra-nanohybrid (Palfique Estelite, Tokuyama Dental, Tokyo, Japan), were used. The properties of the composite resins and the finishing-polishing systems used in the study are shown in Table 1 and Table 2, respectively. Approval for this study was obtained from the Mersin University Clinical Research Ethics Committee, under the ethics committee permission number 2023/838.

Table 1. Properties of composite resins used in the study

Composite resins	Manufacturers	Type	Organic matrix content	Inorganic filler
G-ænial Posterior	GC, Dental Products, Tokyo, Japan	Nanohybrid	UDMA and dimethacrylate co-monomer	Pre-polymerized fillers (16–17 µm). Silica, strontium and lanthanide fluoride. Silica and fluoroaluminosilicate >100 nm, micro silica <100 nm
Estelite® Sigma Quick	Tokuyama Dental, Tokyo, Japan	Supra-nanohybrid	Bis-GMA and TEGDMA	Supra-nano monodispersing spherical filler: SiO_2-ZrO_2. Average particle size is 0,2 µm and particle size is between 0,1 and 0,3 µm (71% by volume and 82% by weight)
*UDMA: Urethane dimethacrylate, BisGMA: Bisphenol glycidyl methacrylate, TEGDMA: Triethylene glycol dimethacrylate				

Table 2. Finishing and polishing systems used in the study

Finishing and polishing system	Manufacturers	Type	Organic matrix content	Inorganic filler
One-Gloss	Shofu Inc., Kyoto, Japan	One-step polishing cups	Aluminium oxide and silicon dioxide	-
Sof-Lex	3M, ESPE, St. Paul, MN, USA	Multi-step polishing disks	Aluminium oxide coated disc	Coarse 60 µm Medium 29 µm Fine 14 µm Super fine 5 µm
Platina Hi-Gloss	PrevesDenpro, India	Polishing paste	Aluminium oxide	-

Preparation of Specimens

The study population was determined using the G*Power program (Version 3.1.9.4, Heinrich Heine University, Düsseldorf, Germany). With an established α of 0.05 and power (p) of 85%, the calculated minimum sample size was n = 90. To consider for potential dropouts, the sample size was increased by 10, resulting in a total of 100 subjects.

Specimens with a depth of 2 mm and a diameter of 6 mm were prepared from each composite resin (50 nanohybrid and 50 supra-nanohybrid composites) using a Teflon mold. The application of composite resins involved the use of a mouth spatula for precise placement within the mold. Sub-sequently, polymerization of all specimens was carried out for a duration of 20 seconds on both the upper and low-er surfaces, employing a VALO LED (Ultradent Products Inc., South Jordan, UT, USA) in accordance with the man-ufacturer's instructions. Composite resins were polymer-ized using a 'mylar strip' to obtain a smooth surface. The output intensity of the curing light was measured for each group prior to polymerization using a radiometer (Blue-phase Meter II, Ivoclar Vivadent, Schaan, Liechtenstein). To ensure consistency, the distance between the light unit's tip and the specimen was standardized with transparent polyester tapes. The specimens were immersed in distilled water at 37°C for a duration of 24 hours. Subsequently, the two distinct composite resins were segregated into five subgroups, each comprising 10 specimens, for subsequent polishing procedures.

Group 1: Finished with mylar strip. No polishing or finishing procedures were applied (Control group).
Group 2: Al2O3 coated one-step polishing cups (One Gloss, Shofu, Kyoto, Japan) in flame-tipped form was applied to the specimens for 20 s under water cooling. **Group 3:** After the specimens were polished with Al2O3 coated one-step polishing cups (One Gloss, Shofu, Kyoto, Japan) in flame-tipped form under water cooling for 20 s, Al2O3 coated polishing paste (Platina Hi-Gloss, India) was applied to the specimen surfaces with a brush.
Group 4: Specimen surfaces were polished for 20 s without water cooling using a multi-steps polishing system (Sof-Lex, 3M ESPE, USA) with Al2O3 abrasive (coarse, medi-um, fine and super fine) polishing disks.
Group 5: The specimen surfaces were polished with a polishing discs (coarse, medium, fine and super fine) using a multi-step disc system (Sof-Lex, 3M ESPE, USA) con-taining Al2O3 abrasive for 20 s without water cooling and then polishing paste containing Al2O3 (Platina Hi-Gloss, India) was applied with a brush.

Color Measurement

Following the completion of the finishing and polishing procedures, the initial color values of each composite resin specimen were assessed with a spectrophotometer (Vita Easyshade V; VITA Zahnfabrik, Germany). Before measurements, the specimen were then placed on a neutral grey background under D65 light source, and the spectrophotometer tip was positioned in contact with and perpendicular to the middle third of the facial surface of the specimen taking care to ensure the same environment and the same time for each specimen. The "L*, C*, and H*" values were measured individually. Each measurement un-derwent three repetitions, and the resulting mean values were calculated. The spectrophotometer was recalibrated according to the manufacturer's instructions after every nine measurements.

Staining Procedure

After the initial measurements, the specimens were kept in coffee (Nescafé Classic, Switzerland) for 144 h, to sim-ulated 6 months of coffee consumption.[17] Coffee solution was prepared by adding 8 g of coffee to 100 ml of boiling water and kept at room temperature (37°C) to mimic the oral environment. The solution was renewed every 24 h. At the end of the 144th h, the specimens were removed from the solution, washed in distilled water and dried with a sponge. The L*, C*, H* values obtained after the second and final measurements were recorded. The preparation of the specimens, the experimental phase and the color measurements were carried out by the one operator to ensure standardization of the study and to obtain subjective data. The color value difference data between two measurements (post-coloring and pre-coloring) were calculated according to the following CIEDE2000 (ΔE00) formula;

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

According to the literature we referenced, 50:50% perceptibility threshold (PT) ΔE00: 0.8 and 50:50% acceptability threshold (AT) ΔE00: 1.8.[20]

Statistical Analysis

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS Inc., Version 23, Chicago, IL, USA). The hypotheses were evaluated at a significance level of $\alpha = 0.05$. Descriptive statistics included the calculation of mean values and standard deviations. The Shapiro–Wilk test confir med that the data followed a normal distribution. A two-way analysis of variance (ANOVA) was employed to assess the signific ance of ΔE00, and multiple comparisons were performed using post-hoc Tukey's tests. The results are presented as mean ± standard deviation (SD), with a significance level set at $p< 0.05$.

RESULTS

According to the results obtained; it was seen that the results of the material, polishing type and the diff erence of these two parameters statistically affectedthecolor change ($p< 0.001$). Theresultsofcolorchangeaccording to mate-rial and polishing type are shown in Table 3. The supra-na-nohybrid composite resin group showed a higher ΔE00 value than the nanohybrid composite resin group.

Table 3. Results of color change according to materials and polishing systems

Factors	F	p
Materials	19.067	<0.001
Polishing systems	24.596	<0.001
Materials * polishing systems	20.674	<0.001

The mean value ±(SD) results of the color change values according to the experimental groups are shown in Table 4. Specimens from both composite groups exhibited color change values above the clinical PT (> 0.8) and AT (> 1.8). Th e control group (Group 1) utilizing mylar strip exhibited the highest ΔE00 value, whereas the multi-steps polishing system (Group 4) yielded the lowest ΔE00 value.

Table 4. Mean value ± standard deviation (SD) results of color change values according to experimental groups

	ΔE00		
Polishing systems	Materials		
	G-aenial Posterior (n=50)	Estelite Sigma Quick (n=50)	Total
Group 1 (n=10)	$7,36 \pm 3,53^{g}$	$18,11 \pm 5,08^{c}$	$12,73 \pm 6,97^{A}$
Group 2 (n=10)	$7,15 \pm 1,43^{fg}$	$11,50 \pm 2,39^{bcdg}$	$9,33 \pm 2,94^{B}$
Group 3 (n=10)	$7,78 \pm 1,66^{fg}$	$7,68 \pm 2,99^{abdfg}$	$7,73 \pm 2,35^{B}$
Group 4 (n=10)	$5,48 \pm 0,96^{efg}$	$3,85 \pm 0,77^{ag}$	$4,67 \pm 1,19^{C}$
Group 5 (n=10)	$9,09 \pm 1,57^{dfg}$	$7,20 \pm 2,73^{abdefg}$	$8,14 \pm 2,37^{B}$
Total	7,37 ± 2,27	9,67 ± 5,75	8,52 ± 4,50

*A-C: No difference between polishing types with the same letter.
**a-g: No difference between polishing types with the same letter.

There was a statistical difference between the two different polishing systems ($p< 0.05$). The additional application of polishing paste caused a non-significant decrease in color change in the one-step polishing system (Group 2 – Group 3) ($p< 0.05$) and a statistically significant increase in the multi-steps polishing system (Group 4 – Group 5) ($p> 0.05$).

DISCUSSION

The composite resins used in the present study exhibited color change depending on different polishing systems. Therefore, the first null hypothesis of the study was rejected. Since the polishing paste used in addition to the polishing systems in the study showed different results according to the polishing system used together, the null second hypothesis of the study was partially accepted.

Regarding the color changes of composite resins composites, there is no definite value in the literature in terms of PT and AT values, and different values are used in the studies.[21,22] Critical parameters /AT and PT) for assessing the color stability of dental materials are reported with a ratio of 50:50%. Specifically, PT is indicated as ΔE00 (color differ-ence) of 0.8, while AT is denoted as 50:50% with a ΔE00 of 1.8.[17]

In this study, composite type and composite type-polish material interaction were found to be effective on the color change value. In the literature, it has been reported that composite resins with small filler particle size can obtain smoother surfaces and therefore less discoloration.[23,24] However, in our study, contrary to this situation, higher color change was obtained in supra-nanohybrid composite resin specimens compared to nano hybrid specimens. We believe that the different content of composite resins is ef-fective in these data.

Among the staining beverages consumed, coffee is one of the most commonly used agents to imitate the daily routine in a laboratory environment.[25] It causes adsorption and absorption of yellow colored substances present in the structure of coffee through the organic phase of resin-based composites and causes color change.[26] The literature stated that it takes an average of 15 minutes to drink a cup of coffee and the average daily consumption is 3.2 cups.[27] It is noted that a simulated coffee consumption duration of 72 hours corresponds to the equivalent of three months of daily consumption. On the other hand, it was determined that hot coffee solution was more effective in color change, and Hui et al.[28] reported that the amount of color change in composite resin specimens was proportional to the increase in temperature, confirming this situation.[29] To simulate oral conditions, a temperature of 37°C and continuous exposure to the staining solution without cycling have been suggested.[30] Considering these facts, in this study, the specimens were exposed to coffee solution for 144 hours in the incubator at a constant temperature of 37°C. This period corresponds to a person's 6 months of coffee consumption.

Discoloration of resin-based composites can be caused by intrinsic factors such as organic and inorganic phase and extrinsic factors such as absorption of coloring beverages by the composite resin.[20] It has been reported that the porous structure of the inorganic filler phase of the composite causes more coloration in dyeing solutions.[31,32] In addition, UDMA, one of the organic monomers, is known to be more resistant to staining than BisGMA and TEGDMA.[6] In many studies in the literature, more color change was obtained in composite resins containing TEGDMA and this was attributed to the high amount of water absorption of TEGDMA as it is a hydrophilic monomer.[10,33-36] Deljoo et al.[33] conducted a comparative analysis of color change between microhybrid and nanohybrid composites. The findings revealed a lesser degree of color change in the nanohybrid composite, which was attributed to the presence of the UDMA monomer within the nanohybrid composite formulation. In our study, the supra-nanohybrid (9,67 ± 5,75) composite group showed a higher ΔE00 value than the nanohybrid (7,37 ± 2,27) composite group and both composite types showed a perceptible (> 0,8) color change. This result is supported by the existing studies in the literature and that have assume it is related to the UDMA content of the nanohybrid composite and the TEGDMA content of the supra-nanohybrid composite.

Discoloration of the surface of composite resins can be reduced by effective polishing procedures.[37] According to the literature, the lowest surface roughness was generally obtained in composites polymerized under mylar strip.[1,38] However, contrary to this, the highest ΔE00 values were obtained for mylar strip specimens in many studies.[17,19,36,39] This result was attributed to the presence of an oxygen-inhibition layer from the mylar strip. Our study aligns with previous research findings, as the mylar strip group exhibited the highest observed color change value, consistent with existing studies.[17,19,36,39]

Differences in the effectiveness of polishing systems are due to the type of abrasive (abrasives containing Al2O3, diamond particles), sizes and shapes (disk, spiral, conical, flame).[17] In many studies in the literature, Sof-Lex Disk polishing system, which gives better results compared to other polishing systems, is a multi-step polishing system containing grains of various sizes and has been reported to be less effective on convex surfaces due to its flat discs.[17,33,40] Another polishing system used in our study, One Gloss one-step polishing system, includes polishing tires in the form of disc, conical tip and flame tip. Similar to the results of many studies, the multi-steps polishing system showed less discoloration than the one-step system in our study.[17,41,42] It is related that the fact that the polishing cups in the form of a flame tip in the one-step polishing system is less effective on the flat surfaces of the composite samples compared to the multi-steps polishing system is effective in the high color change of the one-step polishing system in our study.

There are conflicting results about the effects of additional polishing paste applied to polishing systems on the color stability of restorative materials.[18,19,39] It has been reported that the effectiveness of polishing systems varies depending on the type of abrasives and smoother surfaces are obtained with diamond abrasives which are harder than Al2O3.[17] In a study Güler et al.[42] comparing the efficacy of a multi-step polishing system with the incorporation of a polishing paste, it was observed that the group utilizing the additional polishing paste exhibited a reduced degree of color change. The fact that the polishing paste used in our study was Al2O3 containing, whereas the study in the literature used diamond containing abrasive supports the contradiction in the results. In the study examining the effect of additional polishing paste in a one-step polishing system, the color change was observed to decrease in the group utilizing additional paste, aligning with the findings of our study.[18] In addition, in order to fully compare the effectiveness of the polishing systems used in our study, polishing paste was applied both one and multi-step polishing systems.

CONCLUSION

In this study, the effect of composite resin from 2 different manufacturers and 4 different polishing applications on color change was examined. The limitations of this in-vitro study include the fact that the study was conducted under laboratory conditions and could not fully simulate the intraoral environment, the samples were not subjected to thermal cycling, and no roughness study was performed to support the color change values. Therefore, further studies to compare this results using a more composite resins and polishing systems and including different parameters in the study are needed.

Considering the data obtained from the study within the limitations of this study; it was found that additional polishing paste application to polishing systems affected the color change of composite resins depending on the polishing systems used, the specimens in all composite resin-polishing systems combinations showed less discoloration than the specimens in the unpolished control group and regardless of the composite resin and polishing systems used, all specimens showed color change due to coffee solution.

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Ethical Approval

Approval for this study was obtained from the Mersin University Clinical Research Ethics Committee, under the ethics committee permission number 2023/838.

Peer-review

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Author Contributions

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Conflict of Interest

The authors declare that they have no conflict of interest.

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