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Evaluation of Color and Translucency Changes of PEEK Material Veneered with Single-Shade Composite Resins

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ABSTRACT

Aim: The aim of this study was to evaluate the color and translucency changes of single-shade composites used in veneering polyetheretherketone (PEEK) material after aging.
Materials and Methods: 3 single-shade composites with different chemical structures and 1 conventional composite resin were applied on the PEEK material with a thickness of 2 mm (N=40, n=10). L, a, and b color coordinates of each specimen were measured three times with a spectrophotometer on a black, gray, and white background from the center of the specimen, and the average of these measurements was recorded. The specimens were subjected to 5000 cycles of thermal aging at 5-55°C. After aging, color measurements were repeated. Color changes (ΔE00) and translucency parameters (ΔTP00) of composite resin specimens were determined before and after aging using CIEDE 2000 color formulas. The data obtained were analyzed by one-way analysis of variance and Tukey HSD test ($p<0.05$).
Results: As a result of the study, the color change of all composite resin materials was found to be below the clinically acceptable limit (ΔE = 1.8). The lowest color change was observed in the traditional composite group, and a statistically significant difference was found between the other groups ($p<0.05$). The translucency change of single-shade composite materials was found to be statistically lower than that of conventional composite resin ($p<0.05$).
Conclusion: This study's results show that single-shade composite resins can be used as an optical alternative to traditional composites in direct veneering of the PEEK material.

Tek-Renkli Kompozit Rezinlerle Veneerlenmiş PEEK Materyalinin Renk ve Translusensi Değişimlerinin Değerlendirilmesi

Makale Bilgisi

Makale Geçmişi

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Anahtar Kelimeler:
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Yapay yaşlandırma.

ÖZET

Amaç: Bu çalışmanın amacı polietereterketon (PEEK) materyalinin veneerlenmesinde kullanılan tek renkli kompozitlerin yaşlandırma sonrası renk ve translusensi değişimlerinin değerlendirilmesidir.
Gereç ve Yöntemler: 3 adet farklı kimyasal yapıya sahip tek renkli kompozit ve 1 adet geleneksel kompozit rezin PEEK materyali üzerine 2 mm kalınlığında uygulandı (N=40, n=10). Her örneğin L, a, b renk değerlerinin ölçümü örneğin merkezinden olacak şekilde siyah, gri ve beyaz fon üzerinde spektrofotometre ile 3 kere yapıldı ve bu ölçümlerin ortalaması kaydedildi. Örnekler 5-55°C'de 5000 devir termal yaşlandırmaya tabii tutuldu. Yaşlandırma sonrası renk ölçümleri aynı şekilde tekrarlandı. Kompozit rezin örneklerin renk değişimleri (ΔE00) ve translusensi parametresi (ΔTP00) yaşlandırma öncesi ve sonrasında CIEDE 2000 renk formülleri kullanılarak belirlendi. Elde edilen veriler tek yönlü varyans analizi ve Tukey HSD testi ile istatistiksel analize tabii tutuldu ($p<0,05$).
Bulgular: Çalışmanın sonucunda tüm kompozit rezin materyallerinin renk değişimi klinik olarak kabul edilebilir sınırın (ΔE=1,8) altında bulundu. En az renk değişimi geleneksel kompozit grubunda gözlendi ve diğer gruplar ile arasında istatistiksel olarak anlamlı fark bulundu ($p<0,05$). Tek renkli kompozit materyallerinin translusensi değişimi geleneksel kompozit rezinden istatistiksel olarak daha düşük bulundu ($p<0,05$).
Sonuç: Bu çalışmanın sonuçları PEEK materyaline uygulanan direkt veneerleme işlemlerinde, tek renkli kompozit rezinlerin geleneksel kompozitlere optik açıdan bir alternatif olarak kullanılabileceğini göstermektedir.

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INTRODUCTION

In order to ensure successful restorations, it is imperative for the materials used to possess favorable physical and chemical properties, as well as to closely replicate the color and translucency of the adjacent natural teeth.[1] This is because the esthetics of restorations play a pivotal role in their overall efficacy.[2] The field of dentistry has witnessed significant advancements in recent times, especially in the domain of metal-free treatment options.[3] In this context, several polymers have emerged as promising alternatives to ceramics for dental restoration procedures.[3] Polyether ether ketone (PEEK) is a state-of-the-art polymeric material that has been introduced in the field of dentistry and holds promise as a viable alternative substrate in prosthodontics. PEEK is a high-performance semi-crystalline thermoplastic polymer with a linear aromatic structure.[4,5] Its primary applications in dentistry are the creation of fixed dental prostheses, removable dentures, implant abutments, and components.[6,7] PEEK offers several advantages, such as enhanced biocompatibility, absence of metal, shaping flexibility with dental burs, and optimal physical properties.[4,5] Nonetheless, its primary drawbacks are a grayish color and low translucency, necessitating either resin composite or ceramics veneering, particularly in the esthetic zone.[8]

Achieving a composite restoration structurally and optically aligned with adjacent teeth is paramount in dental esthetic treatment. This level of harmonization is vital to ensuring patient satisfaction and acceptance of the treatment.[9] The utilization of multilayering techniques that rely on resin-based composites with varying opacity and shades has been found to replicate the natural appearance of teeth effectively.[10] However, this restorative procedure necessitates a meticulous selection of shades and a high level of technical proficiency, which can result in increased chair time and cost. Hence, there is a growing trend towards streamlining the treatment process, which has the potential to mitigate technical sensitivities and bolster procedural efficacy.[9]

In the domain of restorative dentistry, the term 'chameleon effect' is utilized to denote the material's inherent capability to assimilate a hue similar to that of the neighboring tooth structure, thereby mimicking the natural appearance of teeth. This effect is a crucial aspect in the restoration process and aids in achieving a seamless blend between the artificial and natural elements of the teeth, thereby enhancing the overall esthetic value of the restoration.[11,12] This specific characteristic of dental property has instigated the creation of innovative dental composites that aim to simplify the process of selecting and reproducing shades. Natural teeth exhibit a range of characteristics, such as translucency, opalescence, and fluorescence, which must be accurately reproduced using resin composite materials during the restorative process to achieve optimal aesthetic outcomes.[13] Translucency is particularly noteworthy for its significant impact on the natural appearance of restorative materials.[14] Recently, resin-based composites have emerged, which are commonly referred to as "one shade" or "single shade" composite resins. These composites are designed to imitate all shades with just a single nominal shade esthetically.[15]

However, to the best of our knowledge, there is no study in the literature on using these new single-shade composites in veneering PEEK restorations. In light of this information, the objective of this study was to evaluate the color and translucency changes of single-shade composites used in veneering PEEK material after aging. The resins used for veneering were three single-shade composites with different chemical structures and a conventional multi-shade nanohybrid composite resin. The null hypothesis was that the color and translucency would not be affected by the composite resin type.

MATERIALS AND METHODS

The PEEK specimens (Coprapeek, White Peaks Dental Systems GmbH & Co. KG., Essen, Germany) were configured as 2 mm thick and 10 mm diameter discs within the 3D design program (Autodesk Meshmixer v3.4.35, Autodesk Inc, San Rafael, CA, USA). They were then saved in standard tessellation language (STL) format and manufactured using a dental milling device (Coritec 550i, imes-icore, Eiterfeld, Germany) (N=40). One surface of the PEEK specimens was meticulously abraded under flowing water using 600-800-1000 grit sandpaper for 1 minute per grit to ensure consistent quality. A layer of A PEEK primer visio.link (Bredent GmbH & Co KG, Senden, Germany) was meticulously applied to the PEEK surface using a brush and subsequently light-cured for 90 seconds in a dual-mode light-curing unit (Labolight Duo, GC Europe, Leuven, Belgium). The prepared specimens were randomly divided into four subgroups (3 single shade and one conventional multishade) based on the applied composite resin (n=10): (1) A nanohybrid composite (Filtek Z550, 3M ESPE) (control), (2) a nanofilled composite resin (Omnichroma, Tokuyama), (3) a nanohybrid composite resin (Clearfill majesty ES-2, Kuraray) and (4) A bulk-fill nanohybrid ormocer (Admira Fusion x-tra, VOCO). Table 1 shows the composition of the tested composite resin materials. Composite resin materials were condensed onto PEEK specimens with a custom-made polytetrafluoroethylene mold (8 mm diameter and 2 mm thickness). Then, transparent glass was placed on top to obtain a flat surface and polymerized for 20 seconds with a light-emitting diode (LED) light (Woodpecker B-Cure Plus, Guilin Guangxi, China). The specimens were placed in distilled water in a light-proof glass bottle with a screw cap for a duration of 24 hours. Initial color measurements were conducted within a color measurement cabinet coated with two layers of neutral gray paint. The cabinet was illuminated with a daylight lamp (D65) (TL-D Graphica 965 18W/965, Philips, Amsterdam, Holland) in accordance with Commission Internationale de l'Éclairage (CIE) standards, utilizing a portable spectrophotometer (Vita Easyshade Advance 4.0, Vita Zahnfabrik). Color change measurements were made on a gray background, and translucency change measurements were made on a black and white background. The spectrophotometer was configured to the single tooth measurement mode for the purpose of measuring the specimens. Prior to measuring each specimen, a calibration process was carried out by inserting the probe tip into the calibration port on the machine. The spectrophotometer probe was then placed perpendicular to the middle of the restorations, and three consecutive measurements were taken. The average value of these measurements was recorded. This protocol was repeated for all forty specimens. Upon completion of the initial color measurements, the specimens were promptly exposed to artificial aging at 5-55 °C (5000 cycles). The color measurements were conducted following the same procedure as the initial measurement, and the color difference and the relative translucency difference were determined using the ΔE00 formulas:

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L^*}{K_L S_L}\right)^2 + \left(\frac{\Delta C^*}{K_C S_C}\right)^2 + \left(\frac{\Delta H^*}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C^*}{K_C S_C}\right)^2\left(\frac{\Delta H^*}{K_H S_H}\right)^2}$$

$$\mathrm{TP}_{00} = \sqrt{\left(\frac{L'_B - L'_W}{k_L S_L}\right)^2 + \left(\frac{C'_B - C'_W}{k_C S_C}\right)^2 + \left(\frac{H'_B - H'_W}{k_H S_H}\right)^2 + R_T\left(\frac{C'_B - C'_W}{k_C S_C}\right)\left(\frac{H'_B - H'_W}{k_H S_H}\right)}$$

Table 1. Compositions of the composite resin materials used in the study

Product	Composition	Type	Manufacturer
Admira Fusion x-tra	Ormocer® Organically modified silicic acid Aromatic and aliphatic dimethacrylates, methacrylate-functionalized polysiloxane, Ba-Al-glass, SiO_2 Filler rate: %84 wt	Bulk-Fill Nanohybrid Ormocer	Voco GMBH, Cuxhaven, Germany
Clearfill Majesty ES-2	Bis-GMA, Silanated barium glass filler, hydro aliphatic methacrylates phobic aromatic dimethacrylate pre polymerized organic filler. Filler rate: %78 wt	Nanohybrid	Kuraray, Okayama, Japan
Omnichroma	UDMA, TEGDMA, uniform sized supra-nano spherical filler (260 nm spherical SiO_2-ZrO_2), and filler Filler content: 79 wt%	Nanofilled	Tokuyama Dental, Tokyo, Japan
Filtek Z550 (Control)	Matrix: BisGMA, UDMA, BisEMA, PEGDMA, TEGDMA Filler type: surface-modified zirconia/silica with a median particle size of 3 µm or less; Non-agglomerated/non-aggregated 20 nm surface-modified silica particles Filler rate: 82 wt%	Nanohybrid	3M ESPE, St. Paul, MN, USA

Abbreviations: UDMA, urethane dimethacrylate; Bis-GMA: bis-phenol-A glycidyldimethacrylate; Bis-EMA, bisphenol-A-ethoxylated dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; PEGDMA, polethylene glycol dimethacrylate. Data are provided by manufacturers.

KC, KL, and KH serve as parametric factors that act as correction terms for experimental conditions. Additionally, RT is a rotation function for the interaction between chroma and hue differences in the blue region.

The data was analyzed using IBM SPSS version 23. The Shapiro-Wilk test was applied to assess the normal distribution of variances. One-way analysis of variance (ANOVA) was employed to compare color and translucency values across different composite resins, and the Tukey Honestly Significant Difference (HSD) test was conducted for multiple comparisons. The significance level was set at $p<0.05$.

RESULTS

The one-way ANOVA results (Table 2) showed significant differences among the color changes and relative translucency parameters of composite resins ($p<0.001$).The mean and standard deviation values of the color changes and relative translucency parameters from composite resins are illustrated in Table 3. However, no significant difference was observed among the single-shade composite resin groups in both color and translucency change ($p> 0.05$). The conventional multi-shade composite resin group showed the lowest color change (0.79 ± 0.06), followed by the supranano spherical-filled composite resin group (1.46±0.15), nanofill composite resin group (1.52±0.11) and nanohybrid filled ormocer based bulk-fill composite resin (1.59±0.09) groups. All composite resin materials' color change was below the clinically acceptable limit (ΔE = 1.8). When relative translucency change was evaluated, the supranano spherical-filled composite resin group showed the lowest translucency change (0.25±0.06), followed by the nanofill composite resin group (0.31±0.08) and nanohybrid filled ormocer based bulk-fill composite resin (0.41±0.21) groups. The conventional multi-shade composite resin group showed the highest relative translucency change (1.08±0.64) with a statistically significant difference with single-shade composite resin groups.

Table 2. Results of one-way ANOVA for change in ΔE_{00} and ΔTP after artificial accelerated aging.

	Type III Sum of Squares	df	Mean Square	F	Sig.
ΔE_{00}	49.23	3	16.219	401.973	**<0.001**
ΔTP	38.649	3	12.883	367.273	**<0.001**

Table 3. Descriptive statistics of color change and translucency change values according to composite resin type

Composite Resin	Admira Fusion x-tra	Clearfill Majesty ES-2	Omnichroma	Filtek Z550 (Control)
ΔE00	1.59 ± 0.09 [A]	1.52 ± 0.11 [A]	1.46 ± 0.15 [A]	0.79 ± 0.06 [B]
ΔTP	0.41 ± 0.21 [a]	0.31 ± 0.08 [a]	0.25 ± 0.06 [a]	1.08 ± 0.64 [b]

[A-B]: There is no difference between composite resins in color change with the same letter, [a-b]: There is no difference between composite resins in translucency change with the same letter

DISCUSSION

The findings of the study showed that the composite resin type produced a statistically significant difference in color and translucency. Thus, the null hypothesis was rejected.

The growing focus on dental aesthetics in recent years has underscored the importance of precise color replication methods. Any inaccuracies in restoring the color of teeth can result in patient dissatisfaction and treatment failure.[16] Research indicates that 80% of patients experience dissatisfaction due to noticeable color variations between their dental restorations and adjacent teeth.[17] Therefore, the accurate selection and replication of shades are essential for ensuring successful restorations.

The CIELab color difference system is commonly employed in the evaluation of study outcomes. However, the CIEDE2000 system, a modification of the CIELab system, offers enhanced color perceptibility and acceptability. In a recent study conducted by Paravina et al.,[18] a group of volunteers, including laypersons, dental students and dentists, dental auxiliaries, and dental technicians, were involved in the observation of ceramics. The study aimed to establish the 50% perceptibility and acceptability threshold: ΔE00 = 0.8 denotes 50% perceptibility, while ΔE00 = 1.8 denotes 50% acceptability. None of the composite resin groups in this study presented results above the clinical acceptability threshold. In the present study, all the single-shade composite resin groups showed color change above the clinical perceptibility threshold. The results of this study are consistent with those of a previous study in which single-shade composite resins were found to be above the clinical acceptability threshold, whereas multishade composite resin was above the clinical perceptibility threshold.[19]

The color stability of composite resins is influenced by the composition of the resin matrix and the type and size of the filter particles. The resin matrix plays a key role in determining the discoloration of composite resins. Various properties of the resin composition, including the chemical variances of resin monomers, the oxidation of unreacted monomers, and the concentration and/or type of initiators, activators, and inhibitors, collectively influence the discoloration potential of composite resins.[20] The color stability of resin monomers is influenced by their hydrophilic nature and water sorption capacity. A hydrophilic resin matrix with high water absorption can not only absorb water but also other colorant fluids, leading to discoloration.[21] On the other hand, filler particles don't absorb water but can attract it to their surface. Water sorption by the resin matrix may result in the hydrolysis of silane and the formation of microcracks, facilitating stain penetration and causing discoloration, thus reducing the restoration's lifespan.[22] It has been documented that resins with a higher degree of water sorption exhibit more pronounced discoloration when subjected to discoloration solutions.[23] Furthermore, it has been affirmed that the BisGMA-based resin matrix displays enhanced water sorption due to its hydrophilic nature, resulting in reduced stain resistance compared to other methacrylate monomers, such as UDMA. Additionally, the increment of TEGDMA content in the resin matrix from 0% to 1% has been associated with a rise in water uptake of BisGMA-based resins from 3% to 6%.[24] In the current study, it is important to note that only the bulk-fill nanohybrid ormocer group lacks TEGDMA and Bis-GMA. Hence, it was anticipated that the color change would be lower in comparison to other single-shade composite resin groups and the conventional composite resin group. However, in line with previous studies, it was observed that ormocer-based composite exhibited a statistically higher level of discoloration compared to the conventional restorative material.[25,26] The discoloration observed can be attributed to the inadequate integration of siloxane particles between the resin matrix and the pre-polymerized microfilm products, potentially resulting from discoloration.[26] Despite the hydrophobic nature of the ormoser-based matrix, improper silanization of the organic and inorganic constituents, and incomplete integration into the resin matrix may facilitate the ingress of water and coloring agents into the composite resin, consequently leading to discoloration.[26] In the current study, similar to previous research,[27,28] it was observed that the color stability of single-shade composites was comparatively lower than that of conventional composites. This may be attributed to their resin matrix composition. The conventional multi-shade composite comprises high molecular weight monomers like BisEMA, which are renowned for their low water sorption, which is attributed to their hydrophobicity and high degree of conversion.[29]

The optical properties of restorative materials are impacted not only by the composition of organic matrix and inorganic fillers but also by including dyes and other chemical agents.[30] Pigments or colorants within a material selectively absorb light at specific wavelengths and promote the scattering of other wavelengths.[31] The reflection and refraction of light at internal interfaces lead to multidirectional scattering within the material.[31] The translucency of the material assumes significant importance in the decision-making process pertaining to the restoration or replacement of dental restorations, particularly in areas emphasizing esthetic outcomes.[32] According to previous studies, BisGMA-based resin materials have demonstrated greater translucency in comparison to UDMA/TEGDMA-based resin materials.[33,34] The observed distinction in translucency between Bis-GMA and silica fillers in comparison to TEGDMA may be attributed to their closer refractive index alignment. Consequently, in the present study, the single-shade nanohybrid composite exhibited higher translucency than the control group. Furthermore, the UDMA/TEGDMA containing single-shade nanofilled composite demonstrated translucency results similar to those of single-shade Bis-GMA containing nanohybrid composite resin. Literature has indicated that nanofilled composites display heightened translucency owing to their smaller filler sizes, which fall below the wavelengths of visible light (380-780 nanometers).[35]

The study is subject to certain limitations. Firstly, due to its in vitro nature, it remains unable to precisely replicate the oral environment. Secondly, while the materials within the oral cavity exhibit concave and convex features following the anatomy, the study utilizes samples with flat surfaces. This may lead to differences in how materials reflect light. Third, a single thickness was used for veneering with composite resin. Different thicknesses may cause different translucencies. Therefore, future studies should investigate the color change of the single-shade composite resins with different thicknesses similar to tooth shape specimens.

CONCLUSIONS

The study's findings demonstrate the potential use of single-shade composite resins as an optical alternative for direct veneering procedures on PEEK material. Although the observed color change exceeds that of conventional composite resins, it remains below the clinically acceptable threshold.

Ethical Approval

This in-vitro study does not require ethics committee approval.

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The authors declare that this study received no financial support.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: IK, Data collection or data entry: IK, İA, Analysis and interpretation: IK, İA, Literature search: IK, İA, Writing: IK, İA.

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