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The Effect of Different Zirconia Core Thicknesses and Veneer Types on Color Stability After Artificial Accelerated Aging

Farklı Zirkonya Çekirdek Kalınlıkları ve Kaplama Tiplerinin Yapay Hızlandırılmış Yaşlandırma Sonrası Renk Stabilitesine Etkisi

Bora AKAT[1]
[1]Department of Prosthodontics, Faculty of Dentistry, Ankara University Ankara, Türkiye

Ayben ŞENTÜRK[1]
[1] Department of Prosthodontics, Faculty of Dentistry, Ankara University Ankara, Türkiye

Merve ÇAKIRBAY TANIŞ[2]
[2]Department of Prosthodontics, Faculty of Dentistry, Gazi University Ankara, Türkiye

Mehmet Ali KILIÇARSLAN[1]
[1] Department of Prosthodontics, Faculty of Dentistry, Ankara University Ankara, Türkiye

ABSTRACT

Objective: The aim of this study to evaluate the color stability of zirconia-based crown veneered with different materials after artificial aging procedures.

Methods: Sixty simple and 60 anatomical designs of cores were milled from yttria-stabilized pre-sintered zirconium oxide blocks for prepared typodont the first premolar. The simple and anatomical cores were divided into 5 subgroups (Layering technique, feldspathic cemented/fused and lithium disilicate cemented/fused). Color measurement was completed via a spectrophotometer with artificial aging procedures. ΔE values were calculated with CIEDE2000 formula. ANOVA was used to evaluate the ΔE values among the groups. Post hoc comparisons between examples were conducted using the Bonferroni test.

Results: The ΔE values of the simple core design (1.5±0.5) were significantly lower compared to the anatomical core group (2.89±1.03; P <.05). The layering group ΔE value (2.37±0.56) was significantly less than the other groups in the anatomical core design (P <.05). Additionally, no significant differences existed in the ΔE values between simple core design groups (P >.05).

Conclusion: All groups were affected by the artificial aging procedures. The simple core designs and layering technique showed the lowest ΔE values. Also, the cementation and fused techniques did not affect the color change of restorations.

Keywords: Dental CAD-CAM, Zirconia-based restorations, Color stability, Artificial aging, Spectrophotometer

ÖZ

Amaç: Bu çalışmanın amacı; farklı malzemelerle kaplanmış zirkonya esaslı kron restorasyonların yapay yaşlandırma işlemleri sonrasındaki renk stabilitelerini değerlendirmektir.

Yöntemler: Prepare edilen standart fabrikasyon tipodont birinci premolar diş için, yttriya ile stabilize edilmiş ve önceden sinterlenmiş zirkonyum oksit bloklardan 60 standart ve 60 anatomik kore tasarımı elde edilmiştir. Sabit ve anatomik kor örnekler karşılaştırılmak üzere 5 alt gruba (Tabakalama tekniği, feldspatik korun simantasyonu / seramik kaynaşması ile bağlantısı ve lityum disilikat korun simantasyonu / seramik kaynaşması ile bağlantısı) ayrılmıştır. Renk ölçümü; yapay yaşlandırma prosedürleri uygulanarak sonrasında bir spektrofotometre ile tamamlanmıştır. ΔE değerleri CIEDE2000 formülü ile hesaplanmıştır. Gruplar arası ΔE değerlerini değerlendirmek için ANOVA, örnekler arasında post hoc karşılaştırmalar için de Bonferroni testi kullanılmıştır.

Bulgular: Standart sabit kor tasarımının ΔE değerleri (1.5 ± 0.5), anatomik kor grubuna göre anlamlı derecede düşük (2.89 ± 1.03; P <.05) bulunmuştur. Anatomik kor tasarımında tabakalama grubu ΔE değeri (2.37 ± 0.56) de diğer gruplara göre anlamlı derecede düşük sonuç vermiştir (P <.05). Ayrıca sabit kor tasarım grupları arasında ΔE değerlerinde anlamlı bir farklılık bulunmamıştır (P > .05).

Sonuç: Tüm test grupları yapay yaşlandırma işlemlerinden etkilenmiştir. Standart kor tasarımları ve tabakalama tekniği en düşük ΔE değerlerini göstermiştir. Ayrıca simantasyon ve kaynaştırma (fuse) teknikleri restorasyonların renk değişimini etkilememiştir.

Anahtar Kelimeler: Dental CAD-CAM, Zirkonya esaslı restorasyonlar, Renk stabilitesi, Yapay yaşlandırma, Spektrometre

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Sorumlu Yazar/Corresponding author: Mehmet Ali KILIÇARSLAN
E-mail: mmkilicarslan@yahoo.com

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INTRODUCTION

Dental applications are provided to enhance both function and also esthetics.[1,2] That's why, full ceramic restorations are used as an alternative to metal-based applications.[3] Zirconia cores with glass-ceramic veneers show an important alternative for metal - ceramic restorations due to the huge physical features of zirconia ceramics and esthetic features of veneering materials.[4,5] Veneering of this core is necessary to achieving outstanding esthetic outputs. The veneer layer is generally manipulated directly. The method has also shown insufficiency of shade uniformity, formation of bubbles, and lack of the skill of the dental technician.[6,7]

CAD-CAM fabricated zirconia cores and CAD-CAM fabricated ceramic veneer combinations represent a relatively new technique.[8-10] The veneer and core can be combined with glass-ceramic powder by only one firing.[11,12] Another way to combine the veneer and core is by using resin cement, which has no firing requirement.[13,14] Kim et al.[7] reported that the color repeatability of the veneering application with the digital technique was important clinically suitable esthetic criteria.

The color suitability and stability features of an esthetic restorations are important to its survival success.[15] The color in ceramics is affected by intrinsic factors like the ceramic composition, and extrinsic factors such as dietary habits.[16-18] The oral environment may negatively affect ceramics. Artificial accelerated aging can simulate oral environments, allowing the evaluation of discolorations in materials over time.[19,20] The most commonly used tests for ceramic materials are prolonged water storage and exposure to ultraviolet light.[21,22]

The color of restorations can be measured with spectrophotometers.[23,24] The Commission Internationale de l' Eclairage (CIE) Lab color system has been used to investigate the color difference between a restoration and tooth.[25] According to a spectrophotometer evaluations the CIELab values of the examples, their color difference (ΔE) is determined.[26-28] The ΔE mean is then compared with a threshold for clinical acceptability to determine whether the color difference is suitable.[29,30] Currently, CIE has suggested the CIEDE2000 formula as a novel method. Previous studies have stated that the CIEDE2000 formula obtains the color difference more accurately than CIELab.[31,32]

Present in-vitro study aimed to evaluate the effect of aging on the color stability of zirconia based single crown restorations veneered with feldspathic or lithium disilicate CAD-CAM materials and fluorapatite ceramic applied with a veneering technique. CAD-CAM fabricated ceramic veneers were connected to 2 different zirconia cores by resin cement or low-fusing porcelain. The null hypotheses were that an artificially accelerated aging procedure would cause a similar color change in all groups and that the core design, ceramic manufacture type, ceramic material, and core-ceramic connection type would not affect the color change.

METHODS

A typodont the first premolar (Phantom Frasaco, Frasaco GmbH) was prepared according to 1-mm chamfer finish line, occlusal anatomical reduction of 1.5–2 mm, and 8° taper. A digital impression was performed with the CEREC Omnicam system (Sirona Dental Systems GmbH). Multilayered designs were performed with either the simple or anatomical core design. The simple core was designed with a 0.5-mm thickness; the anatomical core was anatomically reduced 1 mm from the full crown dimension.

Equal numbers of simple and anatomical designs of 120 cores were milled from yttria-stabilized pre-sintered zirconium oxide blocks (InCoris ZI, Sirona Dental Systems GmbH; Cerec In Lab MC XL, Sirona Dental Systems). The zirconia specimens were sintered in the sintering oven (Sirona in Fire HTC, Sirona Dental Systems GmbH), following manufacturer instructions. After the sintering process, the cores were checked for flaws under light microscopy (Leica MZ12, Leica Microsystem Inc.) and sandblasted with 50-µm aluminum oxide particles (BEGO Korox) with 2-bar pressure for 15 seconds. Ultrasonic cleaning was applied for 5 minutes with distilled water (Whaledent, BIOSONIC, Coltene/ Whaladent Inc.).

According to the veneering procedure and material type, the simple and anatomical core specimens were divided into 5 subgroups, each with 12 samples.

1) Layering Group: Layering was applied as the control group. Fluorapatite ceramic (IPS e.max Ceram, Ivoclar-Vivadent) was applied by a certificated technician to minimize operator-sourced mistakes. Dentin, enamel, and glaze layers were applied regularly.

2) Feldspathic Cemented Group: A CAD-CAM fabricated feldspathic veneer (CEREC Blocs; Sirona Dental Systems GmbH) was cemented to a zirconia core.

3) Lithium Disilicate Cemented Group: A CAD-CAM fabricated lithium disilicate veneer (IPS e.max CAD, Ivoclar-Vivadent AG) was cemented to a zirconia core.

4) Feldspathic Fused Group: A CAD-CAM fabricated feldspathic veneer (CEREC Blocs) was fused to a zirconia core with IPS e.max Ceram.

5) Lithium Disilicate Fused Group: A CAD-CAM fabricated lithium disilicate veneer (IPS e.max CAD) was fused to a zirconia core with IPS e.max Ceram.

The core and veneer were designed together (InLab 16, Dentsply Sirona). Additional scanning of the core was not performed for veneer design. All crowns were standardized with the same final form. The first, a simple core was designed with 0.5-mm thickness, and a veneer was designed with a 2-mm total restoration thickness. The milled simple core and veneer complex was scanned with the CEREC Omnicam system. The scanned crown was used as a biogeneric copy to design the crowns with an anatomical core in exactly the same contour and shape as the simple core crowns. A silicone mold was prepared from digitally fabricated crowns for fabricating the layered crowns.

After controlling the adaptation of the cores and CAD-CAM fabricated veneers, these were connected by fluorapatite fusion ceramic or resin cement. Fusion ceramic and resin cement were applied with a vibrator (Vibroboy SL, Bego). The veneers were seated on the zirconia core with finger pressure, and excess material was removed with hand instruments. The fusion ceramic was sintered according to manufacturer instructions. Resin cement was light-cured from all restoration sites for 20 seconds (Panavia V5, Kuraray Noritake Dental Inc.).

The same expert researcher completed all the color measurements with a spectrophotometer (Vita EasyShade Advanced, Vita Zahnfabrik, Bad Säckingen, Germany). The CIELab values of the restorations' cervical, middle, and occlusal third areas were measured with the spectrophotometer. Color measurements were conducted 3 times in 3 different areas for each restoration, and the average L, a, and b values were recorded.

After the initial color measurements, the restorations were subjected to optical aging (Q-Panel company, Cleveland, USA). For each restoration, an aluminum mold was prepared, and the restorations were inserted into the aluminum mold using transparent silicone (Poly Max Crystal Express, Bison International B.V., Goes, Holland) resistant to UV light and water spray. All restorations were exposed to UV light under water spray via the test machine for 300 hours. Cycles of 8 hours of lighting at 600°C±20°C under a type II lamp (UVB-313) and 4 hours of condensation at 500°C±20°C were repeated for 300 hours. This aging application was equivalent to 5 years of clinical survival.

The later spectrophotometric evaluation was performed under the same initial conditions, following the artificial aging process. Color changes were evaluated using the CIEDE2000 color system before and after each aging test. The CIEDE2000 ΔE values were calculated using following formula:

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

The ΔE_{00} data were considered to be perceptible if they were above 1.30 and clinically acceptable if they were below 2.25.[33,34]

All statistical analysis was conducted using statistical software (IBM SPSS Statistics v22.0; IBM Corp). The Kolmogorov–Smirnov test showed a normal data distribution in all groups. Repeated measures ANOVA was used to compare the ΔE values among the groups. Post hoc comparisons between groups were conducted using the Bonferroni test.

RESULTS

The mean, standard deviations, and statistical differences of the color changes (ΔE) of the simple core design groups and anatomical core design groups are given in Table 1 and Table 2. Zirconia core and ceramic veneer thickness significantly affected the ΔE values. The ΔE values of the simple core design (1.5±0.5) were significantly lower compared to the anatomical core group (2.89±1.03; *P* <.05).

The layering group ΔE value (2.37±0.56) was significantly lower than the lithium disilicate cemented group (3.49±0.78), felspathic fused group (3.41±0.66), and lithium disilicate fused group (3.68±0.55) in the anatomical core design (*P* <.05). The feldspathic cemented group showed statistically similar ΔE values to the other groups (*P* >.05; Table 1). Additionally, the feldspathic cemented group with the simple core design showed the lowest ΔE value (1.95±0.72). However, no significant differences existed in the ΔE values between the simple core design groups (*P* >.05; Table 2).

Table 1: Mean values, standard deviations, lower and upper bound values of anatomical core design groups.

			95% Confidence Interval for Mean	
	n	**Mean±SD**	**Lower Bound**	**Upper Bound**
Layering	12	2.37±0.56 [a]	2,009	2,730
Feldspatic Cemented	12	3.11±0.84 [ab]	2,580	3,655
Lithium Disilicate Cemented	12	3.49±0.78 [b]	2,993	3,991
Feldspatic Fused	12	3.41±0.66 [b]	2,986	3,835
Lithium Disilicate Fused	12	3.68±0.55 [b]	3,332	4,040

SD: Standart deviation
Groups with the same letters do not have statistically significant differences (*P* >.05)

Table 2: Mean values, standard deviations, lower and upper bound values of simple core design groups

			95% Confidence Interval for Mean	
	n	**Mean±SD**	**Lower Bound**	**Upper Bound**
Layering	12	2.01±0.58 [a]	1,642	2,380
Feldspatic Cemented	12	1.95±0.72 [a]	1,497	2,418
Lithium Disilicate Cemented	12	2.35±0.71 [a]	1,900	2,811
Feldspatic Fused	12	2.04±0.51 [a]	3,142	4,944
Lithium Disilicate Fused	12	2.46±0.60 [a]	2,078	2,843

SD: Standart deviation
Groups with the same letters do not have statistically significant differences (*P* >.05)

DISCUSSION

According to these results of this study, the null hypothesis was partially rejected. The ΔE values of restorations were affected by the core designs. The simple core design groups showed lower ΔE values than the anatomical core design groups. Further, the anatomical core design groups and layering technique ΔE values were significantly lower than the CAD-CAM groups. Ceramic materials and core-ceramic connection presented similar color differences for the restorations with the anatomical core design. On the other hand, the simple core design groups were not affected by the ceramic manufacture type, material, or core-ceramic connection type.

The color of dental restorative materials can be measured visually or instrumentally reported that correctly matching shade was 5 times more likely via Vita Easyshade spectrophotometer than the visual method.[28] In this in vitro study, the color change was evaluated by a spectrophotometer (Vita Easyshade) because of its ability to simulate reproducible measurements free of the subjective effect of color.[14,26] This spectrophotometer also measures a small area on the teeth or materials, determined by the 3-mm diameter of the optical probe aperture.[35-37] Three repeated measurements were performed in a central area of all restorations, and the mean value for the L, a, and b were applied to the CIEDE2000 formula (ΔE_{00}) to obtain color differentiation caused by the experimental variables.[38]

The color differences of all groups were calculated via the CIEDE2000 formula. CIEDE2000 has been recommended instead of CIELab because it provides a better fit for measuring the color difference and acceptability threshold for dental ceramics and corrects the nonuniformity of the CIELab color space.[31,32] Many studies have found a clinically acceptable color difference value of 2.25 for CIEDE2000.[33,34] In the present study, color difference which is clinically acceptable, was determined as 2.25. The anatomical core groups exhibited ΔE values above the clinically acceptable range. Additionally, the lithium disilicate cemented and fused subgroups showed values above 2.25, unlike the layering and feldspathic cemented and fused subgroups. The feldspathic cemented, layering, and feldspathic fused groups represented the lowest ΔE values at 1.95±0.72, 2.01±0.58, and 2.04±0.51, respectively. The highest color change was observed for the lithium disilicate subgroup of anatomical design (3.68±0.55).

Choi et al.[38] reported that the color stability of all CAD-CAM ceramic materials except resin nanoceramics was found clinically acceptable. A previous study reported that lithium disilicate was the greatest color change–resistant material.[39] However, the color change of the anatomical core design groups (2.37±0.56 to 3.68±0.55) and simple core design groups veneered with lithium disilicate (2.35±0.71to 2.46±0.60) showed clinically unacceptable ΔE values. Kang et al.[40] indicated that CAD-CAM fabricated lithium disilicate ceramics were been affected by different veneer and core thicknesses. In the current study, the lithium disilicate with simple core design groups were affected more than the feldspathic ceramic with simple core design groups. The other simple core design groups' ΔE values were in the acceptable range (1.95–2.04).

After the artificial aging procedure, the lowest ΔE value was found for the feldspathic cemented subgroup of the simple core design. Similarly, Karaokutan et al.[19] reported that the ΔE values of felspathic ceramics after artificial aging were clinically acceptable for inlay restorations.

Dikicier et al.[41] indicated that different core thicknesses affected the color stability of ceramic materials. Similarly in this study, the core thickness affected the color change of restorations. The simple core design (0.5 mm) showed lower ΔE values than the anatomical core design (1 mm). The decreased core thickness caused a decrease in color change. However, the relationship between color difference and core thickness was not significant for all the restoration groups. The layering technique was not affected by the core thickness. The layering subgroup with anatomical core design showed a lower color difference than the lithium disilicate and feldspathic subgroups with anatomical core groups. However, this ΔE value was above the clinically acceptable value (2.37±0.56).

CAD-CAM fabricated veneers were connected to a zirconia core structure by fusion ceramic or resin cement.[11-14] Fusion ceramic and resin cement showed similar ΔE values. The connection type didn’t apparently affect the color stability of the restorations.

The color stability of the materials used in restorations is important. Several conditions affect materials in the oral environment that are susceptible to discoloration.[19] Different artificial aging simulations can be applied to compare the color stability of dental materials.[41] A lot of methods deal to extrinsic factors, including environmental conditions.[20,42,43] In the current study, all groups were subjected to UV and water spray, and artificial aging led to color change in all groups and increased the ΔE parameter of the anatomical core design groups beyond the critical threshold. Although significant color changes were obtained after artificial accelerated aging for all groups, the anatomical core groups had higher deterioration values than the simple core groups.

There is a correlation between surface roughness and the color change of ceramic materials. Tang et al.[44] tested the textures of 5 different ceramics for zirconia frameworks and indicated that veneer ceramics were changed by an artificial accelerated aging test. In the present study, surface texture change after artificial accelerated aging may have affected the color change of ceramic materials. According to another theory, the metal oxides necessary to observe acquired color shades can break down under UV radiation and may change the color of ceramics.[45] Therefore, the effect of different core thicknesses and veneer materials should be investigated with further in vivo studies.

CONCLUSION

Within the limitations of this study, these conclusions can be drawn:

1) All groups were affected by the artificial aging procedures.
2) The simple core designs showed lower color change than the anatomical core designs.
3) The lowest ΔE values were detected for the layering group (IPS e.max Ceram).
4) The cementation and fused techniques did not affect the color change of restorations.

Etik Komite Onayı: Bu çalışmada kullanılan dişler typodont yapay plastik dişlerdi. Dolayısıyla herhangi bir etik kurul yazısı mevcut değildir.
Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Fikir –M.A.K; Tasarım –M.A.K; Denetleme – A.M, B.A, A.S, M.Ç,T, M.A.K; Kaynaklar — A.M, B.A, A.S, M.C,T, M.A.K; Malzemeler — B.A., M.Ç,T, M.A.K.; Veri Toplanması ve/veya İşlemesi –A.M, B.A, A.Ş, M.Ç,T, M.A.K.; Analiz ve/veya Yorum – A.M, B.A, A.Ş, M.Ç,T, M.A.K.; Literatür Tarama– A.M, B.A, A.Ş, M.Ç,T, M.A.K.; Yazıyı Yazan – M.A.K.; Eleştirel İnceleme – M.A.K.
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