RESEARCH ARTICLE

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In Vitro Evaluation of Color Stability of Different Ceramic Crown Systems

Yaşar Kemal YAZGAN [1, a]
Emrah ÇAYLAK [2, b]
Semih BERKSUN [3, c]

[1] Cankiri Karatekin University, Faculty of Dentistry, Department of Prosthodontics, Çankırı, TURKIYE

[2] Girne American University, Faculty of Medicine, Department of Biochemistry, Girne, TRNC

[3] Ankara University, Faculty of Dentistry Department of Prosthodontics, Ankara, TURKIYE

[a] ORCİD: 0000-0002-0557-421X
[b] ORCİD: 0000-0003-0408-9690
[c] ORCİD: 0000-0003-0731-4750

Objective: The aim of this in vitro study is to compare the color stability of 3 different heat pressed all-ceramic crown systems [creation press, injectable pressable system (IPS) empress and finesse].

Materials and Methods: A total of 140 crowns were prepared for 7 groups (n=20) on metal dies, representing the maxillary right central incisor. Colors were measured before and after a total of 500 thermal (5 and 55°C) container baths. Measurements of color change values were performed by a chromameter. One-way analysis of variance was used to compare the data.

Results: The average color change of the tested groups ranged from 0.671 to 1.513. Analysis revealed that there were no significant differences in the mean color change values among the groups (p>0.05). Statistical analysis shows that all ceramic groups have the same, nearly equal color change values.

Conclusion: Color stability of all heat pressed all-ceramic crown systems and metal-ceramic systems are not influenced by 24 hour storage and 12 seconds 500 cycles of 5 and 55°C distilled water thermal process.

Key Words: *Ceramic crowns, color, aesthetics*

Farklı Seramik Taç Sistemlerinin Renk Stabilitesinin İn Vitro Olarak Değerlendirilmesi

Amaç: Bu in vitro çalışmanın amacı, 3 farklı ısı preslenmiş tamamen seramik taç sisteminin [oluşturma presi, IPS (enjekte edilebilir preslenebilir sistem) ve finesse] renk stabilitesini karşılaştırmaktır.

Gereç ve Yöntemler: Metal kalıplar üzerinde maksiller sağ santral kesici dişi temsil eden 7 grup (n=20) için toplam 140 kron hazırlandı. Renkler, toplam 500 termal (5 ve 55°C) kap banyosundan önce ve sonra ölçülmüştür. Renk değişim değerlerinin ölçümleri kromametre ile yapıldı. Verileri karşılaştırmak için tek yönlü varyans analizi kullanılmıştır.

Bulgular: Test edilen grupların ortalama renk değişimi 0.671 ile 1.513 arasında değişmiştir. Analizde gruplar arasında ortalama renk değişim değerlerinde anlamlı fark saptanmadı (p>0.05). İstatistiksel analiz sonuçları bize tüm seramik gruplarının aynı, neredeyse eşit renk değişimi değerlerine sahip olduğunu göstermektedir.

Sonuç: Tüm ısı preslenmiş tüm seramik taç sistemlerinin ve metal-seramik sistemlerin renk stabilitesi 24 saat depolama ve 12 saniye 500 döngü 5 ve 55°C damıtılmış su termal işleminden etkilenmemektedir.

Anahtar Kelimeler: *Seramik kronlar, renk, estetik*

Introduction

The size, shape, surface structure, light transmittance, and color properties of natural teeth can be obtained in fixed crown bridge by ceramics. Over time, the increase in aesthetic expectations and potential biological risks and allergic reactions of metals has led to the development of metal-free restorations. It is known that metal-free restorations are referred to as full ceramic restorations. Although all-ceramic restorations have not yet reached the level of metal-supported ceramics in terms of resistance, their biological compatibility and aesthetic quality have increased their up-to-datedness. Recognition and widespread use of full ceramic crown systems day by day can be attributed to biocompatibility and aesthetic quality features. Despite these positive properties, ceramics are generally fragile and can crack or break rather than undergo plastic deformation in the face of forces (1-4).

The recognition of full ceramic systems day by day has enabled many new products to be introduced to the market by various companies. Today, many dental ceramic manufacturers produce press ceramic systems such as creation press-ceramics, IPS (injectable pressable system) empress and finesse all ceramic (5-7). Especially, full ceramic systems applied by injection technique (IPS empress) have become the center of attention of clinicians with their ease of application, mechanical resistance and aesthetic quality. Aesthetic quality, on the other hand, is based on color measurements, in which color stability is evaluated based on the effect of aging by shocks (1-7).

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Yazışma Adresi
Correspondence

Emrah ÇAYLAK
Girne American University, Faculty of Medicine, Department of Biochemistry,
Girne - TRNC

emrah333@hotmail.com

In this study, it is aimed to compare the full ceramic systems that are applied with injection technique and which are presented as similar to each other. The consistency of the different full ceramic crown systems subject to our research in terms of obtaining the target color was evaluated.

Materials and Methods

Research and Publication Ethics: This retrospective study was conducted after receiving approval from the local ethics committee (129826/2002). The population of this study consisted of 1600 patients in Ankara University Oral and Dental Health Department in 2002. 140 people were included for the study.

Population and Sample: The population of this study consisted of 1600 patients in Ankara University Oral and Dental Health Department in 2002. 140 patients were included for the study. The sample size was calculated using G*Power V3.1.9.2 program. The effect size was calculated as 1.53 based on a similar study that compared the color change values of metal dies, representing the maxillary right central incisor in all-ceramic materials. The minimum number of crown samples required for the statistical analysis was calculated by power analysis for all experimental groups. According to this effect size, it was planned to recruit 20 samples to each subgroup (n=140) with an 80% confidence level and 80% study power. Colors were measured before and after 500 thermal (5 and 55°C) container baths. Measurements of color change values were performed by chromameter. One-way analysis of variance was used to compare the groups.

Color Measurements of Crown Samples: All 20 samples whose cementation was completed were subjected to color measurement using Minolta CR 321 chromameter (Minolta C., Ltd. Radiometric Instruments Operations, Osaka, Japan). First, a carrier matrix was prepared for the samples. The matrix was prepared with polysiloxane condensation curing impression material (Cavex Stabisil Putty, Cavex Holland BV, Haarlem, Holland). Cemented crowns were placed on the impression material placed in a plastic box. Before the curing was completed, the tip of the chromameter device was pressed to the middle of the sample, and the impression material was adapted to both the crown and the device. It was ensured that the device with 3 mm measuring aperture was not affected by environmental factors. Before each color measurement step, the calibration of the instrument was checked and the calibration check was repeated after every 12 samples. Each cement crown was color measured 10 times. The repeatability of the measurements is also taken into account by changing the position of the device at each measurement stage and placing it on the sample again.

After the cementation process, the crowns whose colors were measured were kept in distilled water at 37°C for 24 hours. Later, the crowns were taken to the thermal aging stage in a thermal cycle device between 5-55°C. After 500 thermal cycles, each crown was re-measured in color. Measurements were repeated 10 times for each crown.

Thermal Cycle Application: The crowns on the metal model whose cementation was completed were kept in a Thelco Model 86 device (GCA precision Scientific Co., Chicago, USA) in 37°C distilled water for 24 hours. It is ensured that the crowns are in full contact with the water. Following this process, the crowns were subjected to thermal aging. Two pools of distilled water at 5 and 55°C in an incubator (Nuve BS 302, Nuve Sanayi Malzemeleri AS., Ankara, Turkey), and the carrier mechanism moving between these two pools constitute the thermal aging system. The samples were allowed to stand for 12 seconds in each bath and 500 thermal cycles were applied. After the thermal aging process, the color of the crowns were measured for the second time.

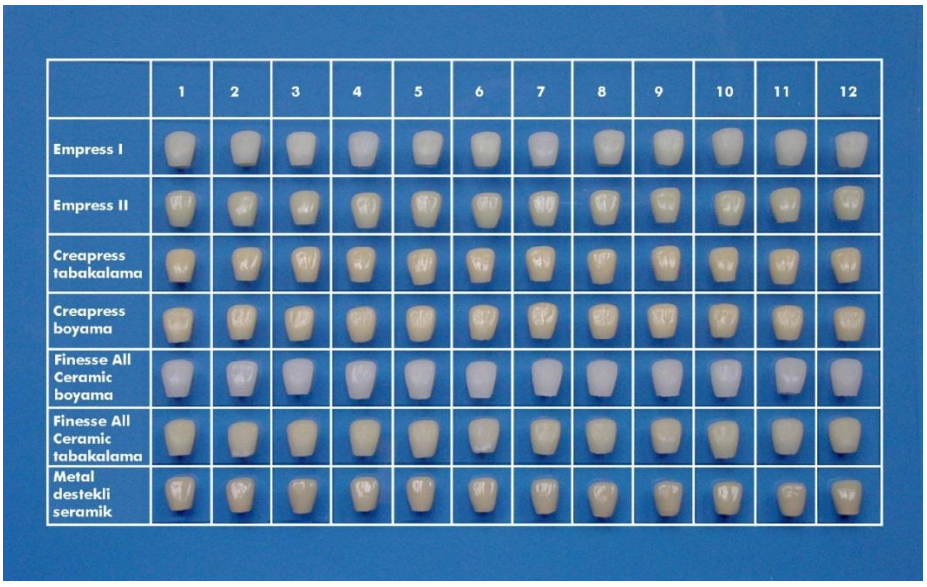

Figure 1. All the seven groups and 84 samples together

Color Measurement Findings: Dentists have difficulties in color matching of ceramic restorations. Physicians state that the colors they prefer cannot be fully achieved in ceramic crowns. Especially in metal-ceramic restorations, the color scales that provide information between the dentist and the laboratory are not sufficient (Figure 1).

It should not be forgotten that color perception can vary from person to person, and may change at different times in the same person. The development of CIE Lab (Commission Internationale de l'Eclairage) colorimetric systems has also provided benefits to dentistry (Figure 2). It is assumed that three coordinate axes are perpendicular to each other in the CIE Lab color space. 'L' axis represents color values between black and white. The 'a' axis represents the color values between green and red. The 'b' axis indicates the color values between blue and yellow. It is possible to define each color with three values defined on the aforementioned three axes. In addition, the difference between these two colors can be found by measuring the changing L, a, b values to calculate globally the color change of an object in which we have recorded the L, a, b values (8-10).

In order to calculate the difference, first the L value (L) of the first color was subtracted from the L value (L_2) of the second color ($L - L_2$), the value obtained from this subtraction is ΔL. $\Delta L = L - L_2$. The same procedure was followed for 'a' and 'b' values; ($\Delta a = a - a_2$, $\Delta b = b - b_2$), is placed in the formula below where we could find the color difference in a single value. The resulting ΔE gives the color change value between the two colors (11, 12).

$$\Delta E = \sqrt{(L - L_2)^2 + (a - a_2)^2 + (b - b_2)^2}$$

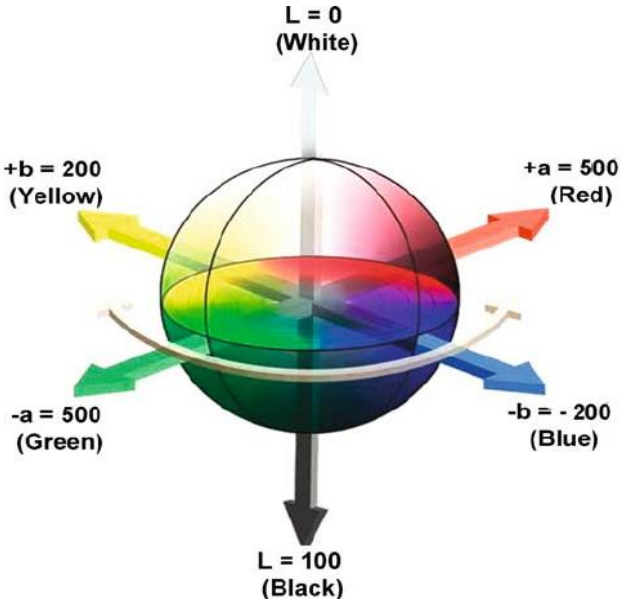

Figure 2. CIE Lab color system

Statistical Analysis: The study findings were analyzed using the SPSS program (Statistical Package for Social Sciences 22.0, USA). The Levene test was used to evaluate the homogeneity of the data, while the Kolmogorov-Smirnov test was used to determine if the data followed a normal distribution. It was found that the data did not show a homogeneous and normal distribution. Due to the sample size of the groups being compared, using the Kruskal-Wallis H test was more appropriate, a non-parametric equivalent of One-Way ANOVA. Since a non-parametric test was preferred, only descriptive values were used.

Results

In this study, seven types of ceramic crown restoration types (IPS Empress, IPS Empress2, Creapress layering, Creapress painting, Finesse layering, Finesse painting and metal-supported ceramic crowns) were used for color measurement operations. The seven groups mentioned consist of samples in the form of 12 crowns each. When ceramic crown restorations before and after thermal cycle, L, a, b numerical color measurement data of CIELAB colorimetric system and delta E (ΔE) averages of these data are evaluated with a global perspective, statistically by one-way analysis of variance. Comparison of ΔE values of all ceramic crowns prepared with different systems before and after thermal cycle is shown in Table 1. The data obtained from color measurements were calculated with the ΔE formulation to include all color elements and some changes were observed in each group. However, no statistically significant difference was found between the ceramic crown groups in terms of color change. In conclusion, it can be said that ceramic restoration systems cannot fully reflect the targeted A2 scale color.

Table 1. Evaluation of color measurement differences before and after thermo-cycles

Material (n=12)	ΔE values*
Empress 2	1.019 (0.891/2.429)
Empress 1	1.433 (0.842/3.576)
Creapress staining	0.858 (0.441/1.982)
Creapress layering	0.671 (0.501/1.421)
Finesse FT1 staining	1.513 (0.534/2.678)
Finesse A2 layering	1.296 (0.953/2.874)
Metal fixed ceramic finesse	1.235 (0.316/4.089)

*Results are represented as median (Interquartile Range-IQR)

Comparison of the differences in L, a, b values of all ceramic crowns prepared with different systems and before and after thermal cycle are presented in Table 2. When the L, a, b numerical color measurement data of the CIELAB colorimetric system using one-way analysis of variance are evaluated statistically, there was a difference between the ceramic groups before the thermal cycle 'L' values ($P<0.001$). In the same way, the difference between the 'a' values and the 'b' values was significant ($P<0.001$).

Table 2. Comparison of the differences of L, a, b values of all ceramic crowns

Material	ΔL*	Δa*	Δb*
Empress 2	0.595 (0.361/1.082)	-0.180 (-0.109/-0.345)	0.418 (0.263/0.812)
Empress 1	1.168 (0.765/2.101)	-0.003 (-0.001/-0.007)	0.688 (0.101/1.205)
Creapress painting	0.090(0.079/0.99)	0.310 (0.053/0.524)	0.166 (0.080/0.201)
Creapress layering	0.161 (0.048/0.198)	-0.062 (-0.021/-0.099)	-0.085 (-0.057/-0.086)
Finesse FT1 painting	0.144 (0.054/0.252)	0.026 (0.011/0.096)	0.018 (0.0083/0.1)
Finesse A2 layering	-0.121 (-0.015/-0.302)	0.036 (0.024/0.076)	0.316 (0.178/0.495)
Metal fixed ceramic finesse	-0.242 (-0.090/-0.512)	0.104 (0.023/0.356)	-0.136 (-0.136/-0.287)

*Results are represented as median (Interquartile Range-IQR)

Likewise, the results of the Kruskal-Wallis test conducted to determine different groups, it was revealed that all three-color elements (lightness-L, darkness-a: green and red-b: blue, yellow) showed a difference in different distributions in each ceramic group without being related to each other ($p<0.001$).

Discussion

In prosthetic approaches, it is not enough to reflect only the shape and resistance of natural structures to restorations. The color, light transmittance, fluorescent effect, brightness and light reflection properties of natural teeth should also be present in the restorations. Especially in ceramic restorations that are widely used, the issue of color is important in terms of meeting aesthetic expectations. As is known, the colors of natural teeth can be reflected in restorations with metal-supported ceramics, but the fact that the metal substrate is not light-permeable creates difficulties in obtaining the desired aesthetic properties. Physicians and individuals make color selection by visually comparing natural teeth with color scales when choosing colors. It becomes difficult to create satisfactory colors for physicians and individuals. To overcome these problems, systems are needed in which the colors of natural teeth are evaluated and scales are created in the light of these evaluations (13).

Poor oral hygiene among denture wearers is well documented. As a result, these patients suffer from denture-related stomatitis, which occurs mainly due to dental plaque accumulation over prolonged period. Thus, the denture wearers must follow a strict denture cleansing method to prevent biofilm formation on the denture surface. Denture cleansing with tooth brush and dentifrice or soap is the most commonly practiced method due to its simple technique, low cost, and proved efficacy in removing organic deposits. On the contrary, brushing with dentifrices significantly impacts the form of wear and roughness of restorative and prosthetic materials. The wear and roughness of acrylic dentures favor biofilm formation and staining, in addition to the loss of surface details and diminished gloss (14). They said that thermal cycling (TC) is a valid method to simulate in-vitro aging of dental materials. Although, there is no standardized TC protocol applied for laboratory testing of dental materials, the specimens in the current study were subjected to 10,000 thermal cycles that represented one year of oral simulation. The authors held the specimens alternatively first in 5ºC cold water and then in 55ºC hot water baths by ISO TS 11405 Technical Specification. This repeated exposure to cold and hot bath mimics the thermal stresses occurring in the oral cavity to which the denture resin materials would be exposed due to the consumption of cold and hot beverages. This TC process in wet conditions may cause denture polymer degradation, and heat stress may increase water sorption, causing the absorbed water to behave as a plasticizer and soften the denture, thus affecting the denture resin properties (9, 14).

As the patient's demands for improvement of appearance continuously increase, the use of esthetic restorations becomes widely required; shade selection in dentistry was reported to be via two common methods, visual and instrumental. Even though color measurements by evaluation between patient's teeth and standard shade guide is the most popular procedure, the individual variations between dentists, shade guides, and technicians impair standardization and make tooth color selection a very critical matter. It is also affected by many other factors following occasional faults in appearance resembling of restoration to natural teeth as the traditional shade selection process is a subjective evaluation even under ideal condition (15).

Uchida et al. (16) studied the color changes of dental composites with the CIELAB system using the Minolta CR-200 chromameter. They found that the change in the value of ‘b’ of the CIELAB system was significant. In other words, they found that composites turn yellow in the oral environment, while light-colored composites are more prone to turn yellow. Douglas (2000), in his study examining the color stability of indirect resin systems, did not find any acceptable differences between the groups after 300 hours of decaying. However, it is noted that the color stability of each group differs. In addition, the two resin groups showed the same color change as the ceramic group, which was the control group.

In our study, it was aimed to determine the consistency of ceramic crown samples in obtaining A2 color scale color, color changes that may occur after the thermal cycle and soaking processes. According to the data, as a result of statistical evaluation processes, we found that limited aging processes do not cause color change. Uchida et al. (16) found significant color change in composites after aging processes. Similarly, Douglas et al. (8) also found a significant color change in

composites, but stated that it was within clinically acceptable limits. Hekimoglu et al. (17) investigated how ceramic laminates are affected by aging processes in terms of color. They found that aging processes did not make a difference on color. In our study, when we statistically examined the ΔE value indicating the color difference of the CIELAB system, we determined that the aging processes did not make a difference. However, when we examined the 'L', 'a' and 'b' values of the CIELAB system one by one, we found that only the change in the value of 'b' was significant.

Statistically significant differences were also found between the L, a, and b values in the measurements performed after the application of thermal decaying. In line with these results, using different ceramic systems in clinical applications based on a single scale color may have misleading results. Individual color characterization of cases should be carried out originally, considering the specific color classifications and scales of each system. In addition, measurements of the L, a, b values in the groups where the staining method was applied showed that they were more permeable to light than other groups in terms of light transmission and reflected the basic color elements less. The coloring application has been less successful in capturing the targeted color.

As a result, we evaluated the aesthetic properties of porcelain crown systems in this study. We compared the color consistency and the color stability of fixed full ceramic crown systems applied with the current injection technique. Crown samples prepared on metal alloy dies were aged by thermal cycle processes; color changes were determined among them and before and after thermal aging and their color stability were measured. Metal-supported ceramics with limited aesthetic quality are superior to current all-ceramic crown systems in terms of mechanical resistance but the systems that can meet aesthetic expectations and offer sufficient mechanical resistance are IPS Empress 2 and Finesse painting systems. Ceramic crown systems have an inability to provide a certain scale color that is commonly used. Each ceramic system should be used using its own scale and based on the individual color characteristics of the case. Thermal cycle and soaking processes do not cause changes in the color of ceramics.

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