

The Effect of Laboratory Procedures and Repeated-glazing on Color of Metal-ceramic Restoration

Abstract

Background: Routine laboratory procedures and repeated glazed effect the final color of metal-ceramic restorations (MCRs). Clinicians wonder if the color changes after routine laboratory procedures and repeated glazed is clinically acceptable or not. **Aims:** The aim of this study was to determine the color changes of MCRs after routine laboratory procedures and then glazed for 1, 2, and 3 times. **Materials and Methods:** Forty-five disc-shaped (10-mm diameter and 1-mm thickness) specimens were fabricated from Cr-Co metal-alloy. Bonding agent, first and second layer of shade A₂ opaque porcelain (OP) were applied on the metal specimens. The color of specimens was measured with a spectrophotometer after each procedure and ΔE_1 , ΔE_2 , and ΔE_3 values were calculated. Shade A₂ feldspathic porcelain was applied (2-mm thickness) to all specimens. Glaze was applied on the porcelain for 1, 2, and 3 times and then, the color measured after each procedure and ΔE_4 , ΔE_5 , and ΔE_6 values were calculated. Data were analyzed with one-way ANOVA and Duncan test ($P < 0.05$). **Results:** ΔE_1 that was obtained between the first layer of OP and bonding agent showed the greatest value. ΔE_2 that was obtained between the second and first layer of OP showed the lowest value. After repeated glazed procedures, the final color of the specimens was changed; but, these changes were clinically acceptable ($\Delta E < 5.5$). **Conclusions:** The routine laboratory procedures and glazed for 1,2, and 3 times is effect the color of MCRs; but, the color changes were clinically acceptable ($\Delta E < 5.5$).

Keywords: Color change, glaze, laboratory procedures, metal-ceramic restoration

Introduction

Reproducing the structure and color of a tooth using metal-ceramic restorations (MCRs) is challenging.^[1-3] MCRs are frequently used due to their excellent fracture resistance.^[4] The metal substructure is an essential part of an MCR, as it supplies necessary strength and rigidity for clinical function.^[5-7] However, the metal substrate of an MCR has a negative esthetic effect, especially when the MCR's are used in the anterior esthetic region, depending on the increased light reflection.^[8] The main problem of color replication is the structural differences between natural teeth and MCRs.^[9] Other factors contribute to the esthetic success of dental restorations, such as the ceramic layer's thickness, firing parameters and temperatures, and the number of firings.^[10,11] In addition to translucency, opalescence, fluorescence, surface texture and shape properties, porcelain brand and batches and the

condensation technique of porcelain may also affect the final color of the MCRs.^[10-14]

The metal substructure of an MCR is first covered with opaque porcelain (OP) in a minimum of 2 layers, to mask the metal color, as well as to provide the restoration its basic shade and to develop the metal-porcelain bond. In this respect, OP plays an important role in the development of the shade and the esthetic outcome of the MCR.^[6,15] An initial OP layer with high masking power is applied to the metal substructure to mask the dark metal oxide that promotes the adhesion of porcelain to metal. It has been shown that the color of OP differs considerably after firing at clinically applicable thicknesses on various metal systems. However, the reason for this color change is not clear, and it has been reported that thickness of the OP and/or the susceptibility to diffusion of discoloring oxides during firing might affect the final color of the OP layer when veneered to its metal substrate.^[16,17]

The glazing of porcelain dental restorations is a routine procedure designed to provide

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esthetic and hygienic glass-coated surfaces on the finished restoration.^[18,19] Glazed surfaces result in less plaque accumulation. In addition, glazed porcelain can imitate the appearance and characterization of the natural tooth.^[20] It decreases the exposure of the dental restoration to the oral cavity and provides the necessary smoothness.^[19,21] Nevertheless, an occlusal adjustment is sometimes needed when the adaptation of the restoration is not perfect. In such cases, the porcelain needs to be glazed repeatedly or intraoral porcelain polishing system can be used. Extra glazing procedures may be changed the final color of MCRs.

The CIE L*a*b* system is the international standard for color measurement.^[7] In this system, all colors can be matched by mixing relative amounts of the primary colors red, green, and blue. The red, green, and blue values can be mathematically converted to CIE L*a*b* scales and expressed in CIE L*a*b* color space. The L* axis represents darkness and lightness coordinates, with values ranging from 0 (perfect black) to 100 (perfect white). The a* axis represents chromaticity coordinates: Green is signified by negative coordinates and red is indicated by positive coordinates. The b* axis also represents chromaticity: Yellow is signified by positive coordinates and blue is signified by negative coordinates.^[7,22] The color difference (ΔE) between two objects, or in the same object before and after it is subjected to particular conditions, can be determined by comparing the differences between the respective coordinate values for each object or situation.^[23] The color difference (ΔE) between 2 objects can be calculated using the equation;^[7]

$$\Delta E = ([L_1 - L_2]^2 + [a_1 - a_2]^2 + [b_1 - b_2]^2)^{1/2}$$

The aim of this study was to determine the color changes of MCR after routine laboratory procedures and then glazed for 1, 2, and 3 times. The null hypothesis of the present study is that routine laboratory procedures and repeated-glazing may be effect the final color of restorations.

Methods

Forty-five disc-shaped specimens (10 mm diameter and 1-mm thickness) were fabricated from Cr-Co metal-alloy. The thickness of each disk specimen was controlled with an electronic calipers. The Cr-Co alloy specimens abraded with 110- μ m aluminum oxide powder according to the manufacturer's instructions. First, the bonding agent was applied only a surface of each specimen and then fired. Shade A₂ OP was applied to the specimens with a brush-on application technique. Two layers of OP were fired. The first layer was applied as thin slurry and the second as a brush-on layer to obtain uniform coverage. After each stage of these routine laboratory procedures, the color of each specimen was measured with a spectrophotometer (VITA EasyShade; VITA Zahnfabrik). This system captures the color coordinates using a D65 illuminant (color

temperature 6500° Kelvin) and a viewing angle of 2 degrees. The color of the specimen was measured with the surface facing up against a neutral gray background.^[24] The CIELAB values (L*, a*, and b*) were determined from nine measurements of each specimen, and transferred to a personal computer for analysis. The instrument calibration was evaluated after measurement of each specimen and the instrument was recalibrated. Shade A₂ dentin body porcelain (2-mm thickness) was applied to the specimens and fired. The thickness of each specimen was controlled with an electronic calipers. Finally, all specimen were glazed and fired for 1, 2, and 3 times. The color of all specimens was measured again after each glaze process. In summary, the processes which were applied on the metal specimen;

1. Bonding agent
2. The first layer of OP
3. Second layer of OP
4. Dentin body porcelain
5. The first layer of glaze
6. Second layer of glaze
7. The third layer of glaze.

The color differences (ΔE) were calculated according to the following equation; $\Delta E = ([L_1 - L_2]^2 + [a_1 - a_2]^2 + [b_1 - b_2]^2)^{1/2}$. In this way;

- ΔE_1 = Between the first layer OP and bonding agent
- ΔE_2 = Between the second and first layer of OP
- ΔE_3 = Between the dentin body porcelain and second layer of OP
- ΔE_4 = Between the first layer of glaze and dentin body porcelain
- ΔE_5 = Between the second and first layer of glaze
- ΔE_6 = Between the third and second layer of glaze were calculated for each statement.

The ΔE values determine whether the changes in the overall color of the specimens are perceivable to the human observer. In this study, an ΔE of >2.6 units was used as a baseline of visual significance.^[23] Any specimen with an average ΔE score of >2.6 units was scored as visually detectable, and values above 5.5 ΔE were considered clinically unacceptable. The data were analyzed with statistical software (SPSS, version 17.0; SPSS, Inc, Chicago, Ill, USA). The ΔE values of the specimen after routine laboratory procedures and glazed for 1, 2 and 3 times were analyzed by one-way analysis of variance (ANOVA) at a confidence level of 95%. The Tukey honestly significant difference (HSD) test was used to perform multiple comparisons ($\alpha = 05$).

Results

The means and standard deviation (SD) are listed for each ΔE values in Table 1. The highest mean \pm (SD) was observed in ΔE_1 . The lowest mean \pm (SD) was observed in ΔE_2 . The first layer of OP effected the color of specimens significantly, but the second layer of OP was not. When the dentin porcelain was applied, ΔE values (ΔE_3) was increased. However, when the porcelain was glazed for 1, 2, and 3 times, ΔE values were decreased.

The results of one-way ANOVA of the ΔE values are listed in Table 2. According to the ANOVA result, there was statistically significant differences among the ΔE values.

The Tukey HSD test was used to perform multiple comparisons. According to the Tukey HSD test; there were no significant differences among the $\Delta E_2-\Delta E_6$ and $\Delta E_6-\Delta E_5-\Delta E_4-\Delta E_3$ values. ΔE_1 value was greater than other ΔE values [Table 3].

Discussion

The aim of this study was to evaluate the color changes of metal-ceramic specimens after routine laboratory procedures and glazed for 1, 2, and 3 times. The null hypothesis of this study was accepted. The routine laboratory procedures and glazed for 1, 2, and 3 times effected the final color and $\Delta E > 1$ of all specimens that were noticeable by human eye. After the first layer of OP, the color changes were statistically significant for all specimens. Compared with the first glazing procedure, the second and third glazing procedures demonstrated less effect on the color stability of metal-porcelain specimens.

Color stability is an important factor to ensure the long-term clinical success of MCRs. Therefore, it is important to minimize the factors that influence the processing of the shade of MCRs.^[25]

Table 1: Mean and standard deviation of ΔE values

ΔE values	Mean \pm SD
ΔE_1	4.166 \pm 2.179
ΔE_2	1.394 \pm 0.606
ΔE_3	2.118 \pm 1.242
ΔE_4	1.999 \pm 1.213
ΔE_5	1.959 \pm 1.014
ΔE_6	1.795 \pm 0.893

SD: Standard deviation

Table 2: The results of one-way analysis of variance

	Sum of squares	df	Mean square	F	Significant
Between groups	644.818	5	128.964	77.728	0.000
Within groups	1333.969	804	1.659		
Total	1978.787	809			

Table 3: Tukey honestly significant difference test

Group	n	Subset for alpha=0.05		
		1	2	3
Tukey HSD ^a ΔE_2	135	1.394		
ΔE_6	135	1.795	1.795	
ΔE_5	135		1.959	
ΔE_4	135		1.999	
ΔE_3	135		2.118	
ΔE_1	135			4.166
Significant		0.108	0.310	1.000

HSD: Honestly significant difference

Douglas *et al.*^[23] reported that intraoral color difference could be predicted based on regression analysis that 50% of dentists would accept a color difference if the color difference was 5.5 ΔE , and 50% of dentists could perceive a color difference of 2.6 ΔE values. Yilmaz *et al.*^[15] evaluated the effects of various types of metal alloys on the color of OP after repeated firings and reported that color shifts after repeated dentin firings were imperceptible ($\Delta E < 2.6$) and clinically acceptable ($\Delta E < 5.5$) for each type of metal alloys. In the present study, all ΔE values were clinically acceptable, but ΔE_1 was higher than 2.6 ΔE values. ΔE_1 may be perceived by the dentists and technicians. The color differences would not be perceivable by the human eye ($\Delta E < 2.6$) at every stage, nor after the cumulative color change (glaze firing).^[15]

Possible sources of processing variables in porcelain firing include the thickness and color of the opaque; thickness, color, and translucency of the body and enamel layers; firing temperature; and number of firings.^[13] Although the effect of repeated firings on the color of body ceramic has been shown to be minimal,^[13] O'Brien *et al.*^[13] reported that firing ceramic specimens up to 6 times resulted in perceptual color changes. In addition, for $\Delta E < 1$, the human eye cannot perceive the color difference, as described in previous studies.^[26-28] Ozçelik *et al.*^[17] evaluated the color alterations of different types of metal-ceramic alloys during several stages of metal surface preparation and to determine the effect of those changes on the resulting color of OP. They reported that the color difference of OP for all alloys was not visually perceivable when compared to the target shade ($\Delta E < 2.6$). Aurélio *et al.*^[29] evaluated the effect of extended and conventional (manufacturer-recommended) glaze firings on optical characteristics, residual stress, crack healing, and crystalline structure of four ceramics. They reported that extended glaze firing produces clinically acceptable color alterations.

A number of studies have shown that the glazed porcelain provides a smooth and dense surface, and many have shown that a polishing sequence can produce an equally smooth surface, which may be esthetically better.^[30]

Color differences (ΔE) determined by using spectrophotometers have been used in dental research to describe differences in the color of ceramic systems or in metal-ceramic crowns.^[31] The consistency of the spectrophotometric readings has to be considered as these devices can be subject to problems of over-heating and edge-losses.^[22,32] One group of authors Stavridakis *et al.*^[27,28] attempted to reduce these by rotating each of their samples through 1208 and remeasuring them. The standard deviation for their measurements ranged from 0.1 to 1.5 ΔE_{ab} units which may have adversely influenced their results.

The results of the present study showed that routine laboratory procedures and repeated glazed effected the color

of MCR. However, color changes after all procedures except of ΔE_1 were imperceptible ($\Delta E < 2, 6$) and color changes after all procedures were clinically acceptable ($\Delta E < 5.5$).

Conclusions

Within the limitations, these conclusions were drawn;

1. Routine laboratory procedures effected the color of MCRs. However, it was clinically acceptable ($\Delta E < 5.5$). ΔE_1 value was calculated between the first layer of OP and bonding agent may be perceived by the clinicians and technicians ($\Delta E = 4.166$)
2. Repeated glazed procedure effected the color of MCRs. However, it was imperceptible ($\Delta E < 2, 6$) and clinically acceptable ($\Delta E < 5.5$).

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Conflicts of interest

There are no conflicts of interest.

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