Evaluation of the Effect of Number of Firings on The Color Stability of Dental Ceramics - An in Vitro Study

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Abstract

PURPOSE - The fundamental criterion for achieving an optimal aesthetic is surface colour. In dental ceramics many factors such as material type, surface specifications, number of firings, firing temperature and thickness of porcelain are important to provide an unaltered surface color. The aim of this study was to evaluate the number of firings on the colour stability of dental ceramics. MATERIALS AND METHODS - Metal ceramic crowns are selected as samples in the study, copings are designed in 3shape followed by wax milling and casting. Ceramic layer is added uniformly all over the coping (A2). After initial 2 firings, the crowns are kept for another 3 firings and after each firing, the color of each specimen was measured using a spectrophotometer (VITA EasyShade; VITA Zahnfabrik). RESULTS - When statistical analysis (one way ANOVA) was performed within 3 firings, a statistically significant difference was seen with the following: incisal (P =0.004), middle (P =0.001) and cervical (P = 0.044). CONCLUSION - Within the limitations of this in vitro study the following conclusions can be made, that with an increase in the number of firings it will lead to darker and more reddish / yellowish color.

Keywords Color Change, Repeated Firings, Ceramics, Spectrophotometer, Innovation

1. Introduction

Dental esthetics are intangible, influenced by the wishes of the patient, experience of the clinician and the artistic and technical skills of the ceramist. The patient's perception towards the outcome of a prosthesis is judged primarily based on the shade of the restoration. Patient satisfaction with shade match and reproduction is important while constructing or replacing a restoration and the subject matter has always been a dilemma even for the most eminent practitioner.

Ceramics have a long history in fixed prosthodontics given their superior aesthetics, biocompatibility and optimal mechanical properties and have been gaining popularity since the last decade towards restorative dentistry. It is currently used as core material [1] in all ceramic dental restorations, implant superstructures, and orthodontic brackets. The esthetic success of ceramic restorations depends on several factors like surface or substrate characteristics, marginal integrity, shape and color. Clinically, an appropriate color combination is an utmost important aspect for esthetic dental

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restoration.

Color assessment is looked upn as a complex psychophysiologic process subject to numerous variables. Dentin is considered to be the primary source of color for teeth, which is modified by the thickness and translucency of overlying enamel. The perceived color of natural teeth is a result of light reflected from the enamel surface, in addition to the effect of light scattering within enamel and dentin before it is ultimately reflected back [2]. Clinically, it is important that ceramic restorations reproduce the translucency and color of the natural teeth. There are many factors affecting the match, such as translucency, opalescence, fluorescence, surface texture, and shape [3].

Miller (1987) and Preston (1983, 1985) have described various factors that may influence the dentist and the laboratory technician to acquire an aesthetically acceptable match. Among them, the method of condensation, size of porcelain particles, stage of firing, presence of bubbles and voids, firing temperature, and method of firing each could conceivably affect the physical properties of porcelain, including the shade.[4], [5], [6]. The color of ceramic restorations varies due to many factors such as the thickness of porcelain,[7], [8], condensation techniques, surface smoothness, degree of firings,[9] dentin thickness,[10], [11] and number of firings.[12], [13]. The external view of the layered ceramic may show a specific variability depending on the thickness of the core and veneer ceramic. It is difficult to find the ideal color in inadequate ceramic thickness [14].The translucency or the color shade of the ceramic depends on the type and thickness of the ceramic.[15], [16], [17]. Metal ceramic restorations (MCR) are frequently used due to their excellent fracture resistance [18]. However, the metal substructure of an MCR has a negative esthetic effect due to the increased light reflectivity [19], [20] especially when used in the anterior esthetic zone. The primary challenge of color replication is the structural differences that exist between natural teeth and metal ceramic restorations [21]. Little is known about color changes in ceramic restorations over time. Artificial accelerated aging is a method that simulates the clinical conditions to which materials are subjected and allows the color difference of ceramic restorations over the course of time to be determined.

The Commission Internationale de L'Eclairage (CIE) color system is generally used to identify color changes. This system demonstrates the color parameters of L*, a*, b*and ΔE color changes related with these parameters. The ΔE value reports whether or not there is a color variation that is noticeable to the human eye. If this value is more than 1, the color variation can be noticed visually by 50% of human beings. However, due to the uncontrolled factors around the mouth, values of 3.7 and lower are also clinically acceptable. All colors in the CIE L*a*b* system represents the relative mixture of primary colors of blue, green and red. The values of blue, red, and green are con- verted mathematically to the CIE L*a*b* scale and the color distance is calculated. The L* axis gives the coordinates of lightness and darkness, and these coordinates change between 0 (extremely dark) and 100 (extremely light). The a* axis represents green and red coordinates chromatically; a decreased value of a* in the second measurement compared to the first measurement means a decrease in the red color. The b* axis represents yellow and blue coordinates chromatically; a decreased value of b* in the second measurement compared to the first measurement means a decrease in the yellow color [22]. The aim of the study is to determine the effects of firings on the colour stability of ceramics.

2. Material and Methods

All samples taken for the study were metal ceramic crowns. Copings were designed digitally in 3Shape software with uniform thickness of 0.5mm and was transferred to the imes-icore milling machine to acquire milled wax copings which were later casted to metal copings using conventional casting procedure. The obtained metal copings were trimmed, sandblasted for ceramic layering. Three different locations on the tooth were layered with three different thickness of ceramic material. A ceramic thickness of 2mm in the incisal region, 1.5mm in the cervical and 1mm in the middle third was layered. Conventional veneering ceramic (IPS e.max Ceram; Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the cores to a thickness of 1 mm. Specimens with an A2 veneering porcelain shade (IPS e.max Ceram; Ivoclar Vivadent). Veneering porcelain slurry was condensed and hand vibrated; excess moisture was removed with absorbent paper tissue to minimize porosity. The condensed specimens were fired in an Ivoclar Vivadent Programat P 300 furnace. The calorimetric values have been recorded during the next 3 firings and 2 glazings.

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: a mathematical construct equivalent to average daylight in the Northern Hemisphere) and a viewing angle of 2 degrees. The color of the specimen was measured with the glazed surface facing up against a neutral grey background. The values were determined from 3 measurements (cervical, middle and incisal third) of each specimen, and noted down for analysis. The instrument calibration was evaluated after measurement of each group (n=6), and the instrument was recalibrated. Total color differences were calculated with use of the following equation.

ΔE*= [(ΔL*)2 + (Δa*)2 + (Δb*)2] ½

The L* coordinate is a measure of the lightness-darkness of the specimen. The greater the L* is, the lighter the specimen. The a* coordinate is a measure of the chroma along the red-green axis. A positive a* relates to the amount of redness, and a negative a* relates to the greenness of a specimen. The b* coordinate is a measure of the chroma along the yellow-blue axis; that is, a positive b* relates to the amount of yellowness, while a negative b* relates to the amount of blueness of the specimen. ΔL*, Δa*, and Δb* are the differences in the CIE Color space parameters.[23]

3. Results

Table 1 - comparison of colour stability among 1st firing, 2nd firing and 3rd firings.

Location on crown	Groups	Mean ± SD	SE	95% CI Lower	95% CI Upper	df	F	P-value
Incisal (2mm)	1st firing	4.50 ± 0.99	0.405	3.456	5.543	2	8.161	0.004*
	2nd firing	6.90 ± 2.26	0.922	4.528	9.721			
	3rd firing	9.53 ± 2.80	1.146	6.568	12.479			
Middle (1mm)	1st firing	4.90 ± 1.36	0.559	3.462	6.337	2	22.224	0.001*
	2nd firing	6.71 ± 0.77	0.317	5.899	7.533			
	3rd firing	8.63 ± 0.58	0.237	8.022	9.244			
Cervical (1.5mm)	1st firing	16.61 ± 3.34	1.363	13.110	20.122	2	3.881	0.044*
	2nd firing	19.03 ± 3.74	1.530	15.115	22.984			
	3rd firing	22.26 ± 3.46	1.416	18.625	25.907			

*Significant at P<0.005

P value was obtained from one way ANOVA test

The mean colour stability values after first firing for the incisal (4.50 ± 0.99), middle (4.90 ± 1.36) and cervical (16.61 ± 3.34) after second firing the mean colour stability values for incisal (6.90 ± 2.26), middle (6.71 ± 0.77) and cervical (19.03 ± 3.74) and after third firing the mean colour stability values for incisal (9.53 ± 2.80), middle (8.63 ± 0.58) and cervical (22.26 ± 3.46). When statistical analysis (one way ANOVA) was performed within 3 firings, a statistically significant difference was seen with the following: incisal (P =0.004), middle (P =0.001) and cervical (P = 0.044) (table1) (figure 1-4)

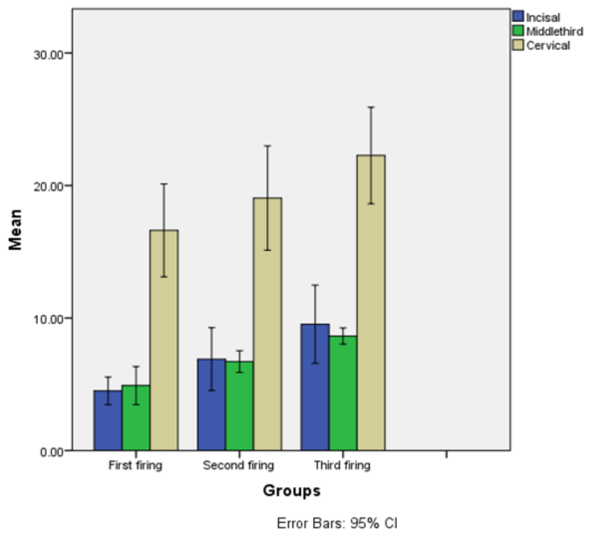

Figure 1 - Means for different veneering porcelain shades and number of firings.

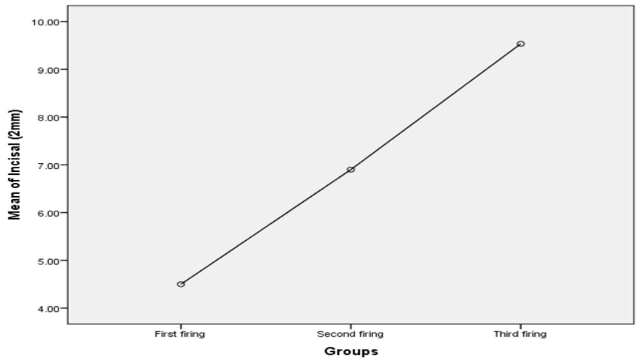

figure 2 - The mean plot shows the difference in mean colour stability values in the Incisal region after first, second and third firing. When statistical analysis was performed within 3 firings, a statistically significant difference was seen (P = 0.004).

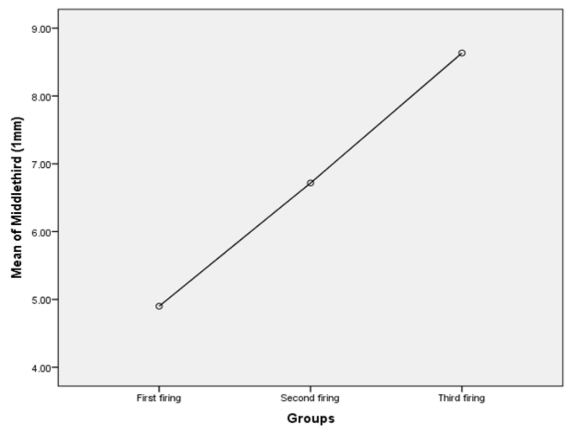

figure 3 - The mean plot shows the difference in mean colour stability values in the middle third region after first, second and third firing. When statistical analysis was performed within 3 firings, a statistically significant difference was seen (P = 0.001).

Table 2- Pairwise comparison of colour stability (ΔE) among 1st firing, 2nd firing and 3rd firings.

Location on crown	Groups	Mean difference	SE	P value
Incisal (2mm)	1st firing vs 2nd firing	3.21	2.034	0.284
	1st firing vs 3rd firing	5.65 +	2.034	0.035*
	2nd firing vs 3rd firing	2.43	2.034	0.473
Middle (1mm)	1st firing vs 2nd firing	1.91 +	0.559	0.010*
	1st firing vs 3rd firing	3.73 +	0.559	0.001*
	2nd firing vs 3rd firing	1.81 +	0.559	0.014*
Cervical (1.5mm)	1st firing vs 2nd firing	2.63	1.246	0.121
	1st firing vs 3rd firing	5.03 +	1.246	0.003*
	2nd firing vs 3rd firing	2.40	1.246	0.166
+ the mean difference is significant at the 0.005 level * significant at P<0.005				

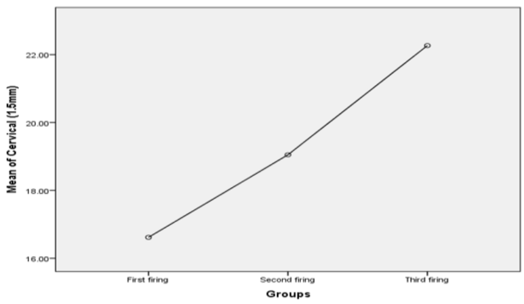

figure 4 - The mean plot shows the difference in mean colour stability values in the cervical region after first, second and third firing. When statistical analysis was performed within 3 firings, a statistically significant difference was seen (P =0.044)

P value obtained from the Tukey HSD Post Hoc test.

The mean colour stability values for the incisal, middle and cervical which are found statistically significant are, in incisal region comparing 1st firing vs 3rd firing is 5.65 +, in the middle the mean colour stability values comparing 1st firing vs 2nd firing is 1.91 +, 1st firing vs 3rd firing is 3.73 + and 2nd firing vs 3rd firing is 1.81 + and in cervical region the mean colour stability values comparing 1st firing vs 3rd firing is 5.03 +. When statistical analysis was performed within 3 firings, a statistically significant difference was seen with the following : in incisal region; statistically significant difference was seen in 1st firing vs 3rd firing (P = 0.035), in the middle; statistically significant difference was seen in all the groups, 1st firing vs 2nd firing (P = 0.010), 1st firing vs 3rd firing (P = 0.001) and 2nd firing vs 3rd firing (P = 0.014) and in the cervical; statistically significant difference was seen in 1st firing vs 3rd firing (P = 0.003) (table2)

Table 3 - Comparison of 1st and 2nd glazing on metal ceramic crowns in relation to colour stability (ΔE).

Group	Mean discrepancy ± SD	SE	t	df	P value
Incisal (2mm) 1st glaze vs 2nd glaze	3.06 ± 0.776	0.316	9.67	5	0.601
Middle (1mm) 1st glaze vs 2nd glaze	1.73 ± 0.688	0.281	6.16	5	0.002*
Cervical (1.5mm) 1st glaze vs 2nd glaze	0.883 ± 0.397	0.162	5.44	5	0.003*
*significant at P<0.005					

P value obtained from paired t test

The mean colour stability values for the incisal comparing 1st glazing vs 2nd glazing is (-3.06 ± 0.776), in the middle, the mean colour stability values comparing 1st glazing vs 2nd glazing is (-1.73 ± 0.688) and in the cervical, the mean colour stability values comparing 1st glazing vs 2nd glazing is (-0.883 ± 0.397). When statistical analysis was performed within 2 firings, a statistically significant difference was seen with the following: middle (P =0.002) and cervical (P = 0.003) (table3).

4. Discussion

In this study, significant changes were identified by the ΔE values. A statistically significant difference was seen on all the surfaces of the teeth in 1st, 2nd and 3rd firings. (P<0.005)

Studies including those of Barghi and Goldberg, Barghi and Richardson [24], [25] and Jorgensen and Goodkind [12] have demonstrated little effect from repeated firings on the color of body porcelain. Whereas O'Brien et al. reported that firing ceramic specimens up to 6 times resulted in perceptual color changes. Repeated firings significantly affected the ΔE color changes [26]. Barghi N, researched the effect of repeated firings on colour and glaze and found that nine firings, a natural glaze layer appears on the surface and the choice of metal alloy did not affect the color or glaze.[25]

Between 1st and 3rd firing there was a significant difference for all thickness groups. In the middle as the thickness was very less (1mm) color stability was minimal and there was a significant difference between each firing group (P<0.005). Heffernan et al studied the influence of core material thickness on its translucency and the influence of core plus ceramic veneer thickness on the overall translucency of the specimens, and concluded that there was a range of ceramic core translucency at clinically relevant core thicknesses.[27], [9]. An increase in ceramic thickness can cause significant differences in the color of the restoration. [17]. According to Uludag et al, [28]. Increases in dentin ceramic thickness tend to yield specimens with a darker and more yellowish/reddish appearance.Mulla and Weiner,[29] reported that color change occurs especially after the first firing, same with our study.

No significant differences were found between the metal ceramic specimens fired 2 and 4 times, with respect to the L*, a* and b* coordinates [30]. Mulla et al. [29] investigated color change during firing and reported significant color changes during the initial firing, but less distinct changes during subsequent firings porcelain color is stable through five firings. As the number of firings increases, a slight change in color can be detected. These changes are dependent upon the type of porcelain. [31]. MacPhee,P [32] suggested that changes in Chroma occurred on firing of extrinsically applied stains.

Although Kay et al. [7] found that firing porcelain samples up to six times resulted in perceptual color changes in some brands of porcelain, the color differences only ranged from 0.88 to 3.52. The thickness of the veneering ceramic and coping may be considered in terms of the amount of tooth reduction. It has been reported that an increase in the dentin thickness can cause significant differences in the color of metal ceramics.[33], [9]. This has been attributed to diffuse reflection properties of the opaque ceramic, which have less effect on color as the dentin ceramic thickness increases.[34]

MC specimens would demonstrate significant color change after artificially accelerated aging, due to possible degradation of the metal/ceramic interface. Color changes in ceramic materials can occur due to the metal oxide content. Metal oxides are added to the ceramic to obtain appropriate color shades. It is known that the metal oxide bond could easily break down under ultraviolet radiation. Peroxide compounds would then form and would likely change the color of the ceramic material. Color changes after repeated firings can be due to the low color stability of metal oxides during firing. Certain metal oxides are not stable after being subjected to firing temperatures. [35]

When in comparison between the firings after 1st glazing and 2nd glazing, a statistical difference was seen in the middle third and cervical regions. (P<0.005)

In previous studies, it is stated that metal oxides did not have stable structures and firing temperatures broke pigments and the color change occurred. [36],[35].

5. Conclusion

1. Within the limitations of this in vitro study, the following conclusions were drawn:
2. an increase in the number of firings will cause darker and more reddish / yellowish colour
3. Colour stability of inadequate ceramic thickness tends to be more unstable if the thickness is below 1.5mm.

6. Limitation and Future Scope -

This particular study has a decreased sample size. Furthermore, confirmation with experiments conducted with a larger sample size and including the all ceramic restorations also.

7. Conflict Of Interest Statement

We declare that we have no conflict of interest.

References

[1] Tan PLB, Dunne JT. An esthetic comparison of a metal ceramic crown and cast metal abutment with an all-ceramic crown and zirconia abutment: A clinical report. The Journal of Prosthetic Dentistry 2004;91:215–8. https://doi.org/10.1016/j.prosdent.2003.12.024.

[2] Seghi RR, Johnston WM, O'Brien WJ.

Spectrophotometric analysis of color differences between porcelain systems. The Journal of Prosthetic Dentistry 1986;56:35–40. https://doi.org/10.1016/0022-3913(86)90279-9.
[3] Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part II: core and veneer materials. J Prosthet Dent 2002; 88:10–5.
[4] Baker CR. Condensation of dental porcelain. The Journal of Prosthetic Dentistry 1960;10:1094–101. https://doi.org/10.1016/0022-3913(60)90220-1.
[5] Hodson JT. Some physical properties of three dental porcelains. The Journal of Prosthetic Dentistry 1959;9:325–35. https://doi.org/10.1016/0022-3913(59)90017-4.
[6] Brecker SC, Charles Brecker S. Porcelain baked to gold—A new medium in prosthodontics. The Journal of Prosthetic Dentistry 1956;6:801–10. https://doi.org/10.1016/0022-3913(56)90077-4.
[7] O'Brien WJ, Kay KS, Boenke KM, Groh CL. Sources of color variation on firing porcelain. Dent Mater 1991; 7: 170–3.
[8] Ozturk O, Uludag B, Usumez A, Sahin V, Celik G. The effect of ceramic thickness and number of firings on the color of two all-ceramic systems. J Prosthet Dent 2008; 100: 99–106.
[9] Hammad IA, Stein RS. A qualitative study for the bond and color of ceramometals. Part II. The Journal of Prosthetic Dentistry 1991;65:169–79. https://doi.org/10.1016/0022-3913(91)90158-s.
[10] Jacobs SH, Goodacre CJ, Moore BK, Dykema RW. Effect of porcelain thickness and type of metal-ceramic alloy on color. J Prosthet Dent 1987; 57: 138–45.
[11] Shokry TE, Shen C, Elhosary MM, Elkhodary AM. Effect of core and veneer thicknesses on the color parameters of two all-ceramic systems. J Prosthet Dent 2006; 95: 124–9.
[12] Jorgenson MW, Goodkind RJ. Spectrophotometric study of five porcelain shades relative to the dimensions of color, porcelain thickness, and repeated firings. The Journal of Prosthetic Dentistry 1979;42:96–105. https://doi.org/10.1016/0022-3913(79)90335-4.
[13] Barghi N, Lorenzana RE. Optimum thickness of opaque and body porcelain. J Prosthet Dent 1982; 48: 429–31.
[14] Douglas RD, Duane Douglas R, Przybylska M, Duane Douglas R, Przybylska M. Predicting porcelain thickness required for dental shade matches. The Journal of Prosthetic Dentistry 1999;82:143–9. https://doi.org/10.1016/s0022-3913(99)70147-2.
[15] Lee Y-K, Cha H-S, Ahn J-S. Layered color of all-ceramic core and veneer ceramics. J Prosthet Dent 2007; 97:279–86.
[16] Antonson SA, Anusavice KJ. Contrast ratio of veneering and core ceramics as a function of thickness. Int J Prosthodont 2001; 14:316–20.
[17] Dozić A, Kleverlaan CJ, Meegdes M, van der Zel J, Feilzer AJ. The influence of porcelain layer thickness on the final shade of ceramic restorations. J Prosthet Dent 2003; 90:563–70.
[18] Wataha JC. Alloys for prosthodontic restorations. The Journal of Prosthetic Dentistry 2002;87:351–63. https://doi.org/10.1067/mpr.2002.123817.
[19] Kourtis SG, Tripodakis A-P, Doukoudakis AA. Spectrophotometric evaluation of the optical influence of different metal alloys and porcelains in the metal-ceramic complex. The Journal of Prosthetic Dentistry 2004;92:477–85. https://doi.org/10.1016/j.prosdent.2004.08.012.
[20] Southan DE. THE SCIENCE AND ART OF DENTAL CERAMICS. VOL. II. BRIDGE DESIGN AND LABORATORY PROCEDURES IN DENTAL CERAMICS, by J. W. McLean. Australian Dental Journal 1981;26:407–8. https://doi.org/10.1111/j.1834-7819.1981.tb04008.x.
[21] Miller LL. Shade Matching. Journal of Esthetic and Restorative Dentistry 1993;5:143–53. https://doi.org/10.1111/j.1708-8240.1993.tb00771.x.
[22] Bolt RA, Bosch JJ, Coops JC. Influence of window size in small window colour measurement, particularly of teeth. Phys Med Biol 1994; 39:1133–42.
[23] Knispel G. Factors affecting the process of color matching restorative materials to natural teeth. Quintessence Int 1991; 22: 525–31.
[24] Barghi N, Richardson JT. A study of various factors influencing shade of bonded porcelain. J Prosthet Dent 1978; 39: 282–4.
[25] Barghi N. Color and glaze: effects of repeated firings. J Prosthet Dent 1982; 47: 393–5.
[26] Gonuldas F, Yılmaz K, Ozturk C. The effect of repeated firings on the color change and surface roughness of dental ceramics. J Adv Prosthodont 2014; 6: 309–16.
[27] Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. J Prosthet Dent 2002; 88: 4–9.
[28] Uludag B, Usumez A, Sahin V, Eser K, Ercoban E. The effect of ceramic thickness and number of firings on the color of ceramic systems: An in vitro study. The Journal of Prosthetic Dentistry 2007;97:25–31. https://doi.org/10.1016/j.prosdent.2006.11.002.
[29] Mulla FA, Weiner S. Effects of temperature on color stability of porcelain stains. The Journal of Prosthetic Dentistry 1991;65:507–12. https://doi.org/10.1016/0022-3913(91)90290-d.
[30] Pires-de-Souza F de CP, de Carvalho Panzeri Pires-de-Souza F, Casemiro LA, da Fonseca Roberti Garcia L, Cruvinel DR. Color stability of dental ceramics submitted to artificial accelerated aging after repeated firings. The Journal of Prosthetic Dentistry 2009;101:13–8. https://doi.org/10.1016/s0022-3913(08)60282-6.
[31] Barghi N, Goldberg J. Porcelain shade

stability after repeated firing. The Journal of Prosthetic Dentistry 1977;37:173–5. https://doi.org/10.1016/0022-3913(77)90239-6.
[32] McPhee ER. Extrinsic coloration of ceramometal restorations. Dent Clin North Am 1985; 29: 645–66.
[33] O'Brien WJ, Boenke KM, Groh CL. Evaluation of some properties of an opaque porcelain fired simultaneously with the body porcelain. The Journal of Prosthetic Dentistry 1994;72:414–9. https://doi.org/10.1016/0022-3913(94)90562-2.
[34] Seghi RR, Hewlett ER, Kim J. Visual and instrumental colorimetric assessments of small color differences on translucent dental porcelain. J Dent Res 1989; 68: 1760–4.
[35] Lund PS, Piotrowski TJ. Color changes of porcelain surface colorants resulting from firing. Int J Prosthodont 1992; 5: 22–7.
[36] Crispin BJ, Seghi RR, Harold Globe. Effect of different metal ceramic alloys on the color of opaque and dentin porcelain. The Journal of Prosthetic Dentistry 1991;65:351–6. https://doi.org/10.1016/0022-3913(91)90224-k.