

Spectrophotometric evaluation of color match of three different porcelain systems for all-ceramic zirconia-based restorations

ALESSANDRO VICHI, DDS, PhD, GIOVANNI FAZI, DDS, MS, MICHELE CARRABBA, DDS, GABRIELE CORCIOLANI, DDS, PhD, CHRIS LOUCA, BSC, PhD & MARCO FERRARI, MD, DDS, PhD

ABSTRACT: Purpose: To determine by a spectrophotometric analysis the variations in color between the intended and the fabricated shades of three different porcelain systems when applied in a standardized thickness on a zirconia core. **Methods:** Three porcelain systems for zirconia based restorations, Ivoclar IPS e.max Ceram, VITA VM9, and Creation Zi-F were tested. Nine disc-shaped (15 mm diameter, 0.5 mm thickness) specimens of VITA YZ zirconia core per group were made comprising a total of 27 discs. Three different shades (A2, A3, A4) of the Vitapan Classical shade guide were investigated. The porcelain veneer total thickness was set at 1.0 mm in all groups. The porcelain stratification was made by applying calibrated layers of porcelain. Thicknesses of single porcelain layers were calculated from drawings retrieved from the manufacturers' instructions. Color parameters (L^* , a^* , b^*) of veneered specimens were measured by a clinical spectrophotometer. Color differences (ΔE) were calculated using a color difference formula. Two-way ANOVA and Tukey's test were used to analyze the data. **Results:** The mean color differences for the three ceramic systems, Ivoclar IPS e.max Ceram, VITA VM9 and Creation Zi-F were respectively 4.1, 2.7 and 3.2, regardless of the shades. VITA VM9 resulted in the best average shade matching among the porcelain systems, even if results with shade A3 were considerably worse than shades with A2 and A4 ($P < 0.05$). Color matching appeared not to be shade dependent ($P > 0.05$) among the tested shades. (*Am J Dent* 2012;25:191-194).

CLINICAL SIGNIFICANCE: Manufacturers' instructions for veneering the zirconia frameworks did not ensure the required color match between intended and obtained shade.

✉: Dr. Alessandro Vichi, Via Derna 4, 58100 Grosseto, Italy. E-✉: alessandrovichi1@gmail.com

Introduction

The problem of color matching a porcelain restoration to natural teeth has been extensively investigated and described.¹⁻³ In the traditional porcelain fused to metal (PFM) restoration, the color matching process of an existing dentition comprises a shade selection performed by the clinician, followed by a shade reproduction in a dental laboratory. Shade selection can be made through a visual assessment using dental shade guides and/or recording color parameters with an electronic device. Shade reproduction is accomplished by the ceramist incorporating different porcelain layers corresponding to dental shade guides, to mimic the different layers in tooth structure. One of the reported concerns with this color matching procedure is the difficulty in closely reproducing the intended shade,^{3,4} particularly considering that variations in thickness of each porcelain layer can significantly influence the final color of the restoration.⁵ The manufacturers of dental porcelains offer limited information about recommended layering schemes to obtain the intended shades, and this information is usually in the form of artistic drawings. For PFM restorations, such recommendations given by the manufacturers are not sufficient to reproduce the desired shade.⁶ Even though the large majority of crowns and fixed partial dentures are still made of PFM, all ceramic restorations and particularly porcelain fused to zirconia (PFZ) restorations have gained popularity in recent years. Excellent mechanical and physical properties associated with optimal biocompatibility make the zirconia a viable alternative to metal frameworks. Although zirconia is a metal-oxide, from an esthetic viewpoint it completely differs from dental alloys for PFM restorations because it is white and relatively translucent, with an appearance more similar to that of a ceramic.⁷ Re-

garding color reproduction with PFZ restorations, the first step in color matching, i.e. shade selection, does not show substantial differences when compared to PFM restorations. Conversely, the shade reproduction phase is done using different porcelain veneering systems (due to the different CTE between metal and zirconia), and on frameworks with different optical properties. Both core material and porcelain veneer have an influence on the final color.⁸⁻¹¹

The instructions given by the manufacturers for the layering process (required in the manufacture of PFM restorations) have been shown to be defective with regard to matching the selected shade. This study verified, by means of a clinical spectrophotometer, whether the manufacturers' instructions on layering patterns allow the fabrication of zirconia based restorations (PFZ) with the required shade. The tested null hypothesis was that the layering process as recommended by the manufacturers allowed the intended shade to be produced. This objective was considered to be satisfactorily achieved when the intended and obtained shade differ by a $\Delta E \leq 3.3$, established as the threshold for clinical acceptability in dental literature.

Materials and Methods

Three ceramic veneering systems were tested in this study: Ivoclar IPS e.max Ceram,^a VITA VM9,^b and Creation Zi-F.^c For each system, three different shades (A2, A3, A4) were selected, for a total of nine combinations. For each combination, three disc-shaped specimens were fabricated, up to a total of 27 specimens. A zirconia core material (VITA YZ^b) was selected as the substrate. Zirconia discs were fabricated by cutting the VITA YZ blocks in a water-cooled low speed diamond saw (Isomet 1000^d). The sections were then reduced to disc shape by manual trimming with a diamond bur used in a laboratory

Table 1. Thickness of porcelain layers expressed in percentages and calculated at 45% of the length of a central incisor starting from the incisal margin. Data obtained from diagrams in manufacturers' instructions.

Porcelain system	Frame modifier		Body porcelain				Incisal porcelain	
			Opaque dentin		Dentin			
	%	mm	%	mm	%	mm	%	mm
Ivoclar IPS e.max Ceram	10	0.10±0.05		none	60	0.60±0.05	30	0.30±0.05
VITA VM9		none		none	80	0.80±0.05	20	0.20±0.05
Creation Zi-F	10	0.10±0.05	10	0.10±0.05	40	0.40±0.05	40	0.40±0.05

handpiece. The disc dimensions were calculated in order to obtain discs of 15 mm in diameter and of 0.5 mm in thickness, after sintering. The specimens were randomly divided into three groups for the veneering procedure. For the VM9 group, the nine specimens were pre-colored using VITA In-Ceram YZ Coloring Liquid,^b as required by the Vita VM9 ceramic system. The samples of this group were immersed for 2 minutes in the YZ Coloring Liquid (shades LL2 for the A2/A3 and LL3 for the A4 specimens) and then dried at room temperature before sintering. The sintering process was performed for all the specimens in a VITA ZYrcomat^b furnace according to the manufacturer's instructions. After sintering, the zirconia discs were inserted in a custom-made cylindrical device (Fig. 1), where the height could be adjusted, and which acted as a guide to produce calibrated layers of veneering ceramic.

The layering patterns for veneering were retrieved from the manufacturers' documentation of the porcelain systems. The information available consisted of drawings from which the thickness of the different layers of liner, dentin and enamel were successively calculated. On the drawings, all of which reproduced an incisor, the measures were calculated at 45% of the length. Values were calculated as percentages.⁶ These values (Table 1) were then used as a reference for the fabrication of the specimens. The total thickness of veneering porcelain was 1.0 mm. The specimen thickness was measured after each firing in order to evaluate the thickness of each layer. A digital caliper (1651 DGT^c) with a 10 µm resolution was used for all the measurements.

The porcelains were fired according to the manufacturers' recommendations in a ceramic furnace (VITA Vacumat 4000T^b). No glazing cycle was performed. The porcelain surface was polished with 320-, 600- and 1200-grit sand paper discs in order to obtain a similar finishing surface in all the specimens. Specimens were then ultrasonically cleaned in distilled water for 5 minutes. Color measurements were made by a clinical spectrophotometer (VITA Easyshade Compact^b). The instrument was placed on its own stand, designed for calibration purposes with the calibration tile used as background (Fig. 2). The procedure to fix the instrument on a stand was preferred as a previous study showed that this arrangement resulted in a higher repeatability than with freehand use.¹² All the measurements were performed with the tip of the instru-



Fig. 1. Custom-made cylindrical device for specimen layering.



Fig. 2. The experimental setup with the Clinical Spectrophotometer VITA Easyshade Compact.

ment perpendicular to the discs and in contact with the disc surface. All of the measurements were consecutively performed after a single calibration process. The "restoration" mode on the spectrophotometer was selected and used throughout the study. The instrument, produced by the same manufacturer as the shade guide, has the color coordinates of each shade of the Vitapan Classical^b shade guide stored in its memory. In "restoration" mode, the instrument measures the color coordinates of the porcelain discs, and then compares these color coordinates with the stored data. The output of the instrument is given directly on the instrument display in terms of lightness, chroma and hue. For the present study the Easyshade Compact was instead interfaced with a computer. Through the use of dedicated software (Shaderite 2HW^b) (Fig. 3), color coordinates were recorded according to CIELab* color space, in which the L* value represents the brightness, a* value represents the redness or greenness and b* value represents the yellowness or blueness. Even if L*, a* and b* are individually relevant, the ΔE value (the distance between points representing colors in the color space having rectangular coordinates, calculated by applying the formula proposed by Clarke:¹³ $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$), is the most important parameter for calculating color differences.¹⁴ It is for this reason, in the present study, that ΔE related data were statistically analyzed.

Having checked that the requirements of normality of distribution (Kolmogorov-Smirnov test, $P > 0.05$) and homogeneity of group variances (Levene test, $P > 0.05$) were met by the data set, two-way ANOVA tests were applied to assess the statistical significance of the influence on ΔE values of ceramic system, shade, and between-factor interaction. The Tukey's test

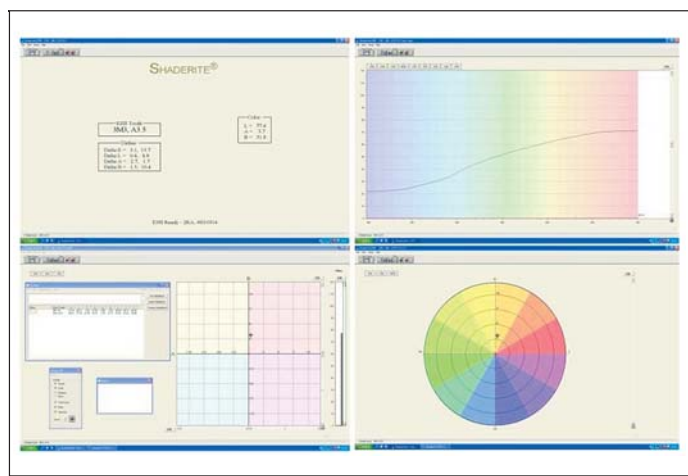


Fig. 3. The ShadeRite software used for the measurements.

was used for post hoc comparisons as needed. In all the analyses the level of significance was set at $P < 0.05$. The SigmaPlot 11.0^f software was used to handle statistical calculations.

Results

ΔL^* , Δa^* , Δb^* and ΔE values were recorded by the spectrophotometer in terms of differences between measured values and data stored in the spectrophotometer. Values of ΔE ranged between 1.3 and 5.0.

The calculated ΔE values and means for both shades and ceramic systems are shown in Table 2. Statistically significant differences within the porcelain system factor, the shade factor and in porcelain system-shade interaction are also reported.

For the A2 shade all the specimens of Vita VM9 (mean of $\Delta E = 1.8$) and sample #1 of Creation Zi-F ($\Delta E = 2.1$) achieved an acceptable color match. For the A3 shade, only sample #2 for IPS e.max Ceram ($\Delta E = 3.3$) and sample #1 ($\Delta E = 1.9$) and #3 ($\Delta E = 2.7$) for Creation Zi-F were clinically acceptable. For the A4 shade, all the specimens of Vita VM9 (mean of $\Delta E = 1.7$) and sample #2 of Creation Zi-F ($\Delta E = 3.3$) achieved an acceptable color match.

Two-way ANOVA (Table 2) showed that the porcelain system had a statistically significant influence on ΔE ($P = 0.002$). Specifically, VITA VM9 (mean $\Delta E = 2.7$) achieved a significantly closer match in color than IPS e.max Ceram (mean of $\Delta E = 4.1$). Creation Zi-F ceramic system (mean of $\Delta E = 3.2$) was statistically similar to VITA VM9 and IPS e.max Ceram.

Conversely, shade per se was not found to significantly influence ΔE ($P = 0.294$). The between-group interaction was significant ($P = 0.001$, Table 2).

Discussion

The results of the present study have indicated that, after following the manufacturers' instructions for layering, the mismatch between the intended and obtained shade was predominantly above the threshold for clinical acceptability ($\Delta E \leq 3.3$), thereby the null hypothesis was rejected.

In the present study, porcelain layering was executed in accordance with the manufacturers' instructions, calculated at 45% of the length of a central incisor starting from the incisal margin, since the central third of the tooth is conventionally reported as the nominal shade. In order to produce intended and uniform thicknesses of the ceramic layers, flat disc-shaped

Table 2. Calculated ΔE values and means for both shades and ceramic systems.

	A2 (a)	A3 (a)	A4 (a)
Ceramic system	Mean (SD)	Mean (SD)	Mean (SD)
IPS e.max Ceram (B)	4.3±0.7 <i>B</i> <i>a</i>	3.7±0.4 <i>AB</i> <i>a</i>	4.3±0.4 <i>B</i> <i>a</i>
VITA VM9 (A)	1.8±0.2 <i>A</i> <i>a</i>	4.4±0.6 <i>B</i> <i>b</i>	1.7±0.7 <i>A</i> <i>a</i>
Creation Zi-F (AB)	3.5±1.4 <i>B</i> <i>a</i>	2.8±1.0 <i>A</i> <i>a</i>	3.4±0.1 <i>B</i> <i>a</i>

Different capital letters denote statistically significant differences among ceramic systems. No statistically significant difference was found within the shade factor (small letters). Different italic small letters denote the significant interaction within each porcelain system. Different italic capital letters denote the significant interaction within each shade.

specimens were preferred to tooth-shaped specimens previously employed.¹⁵ The use of disc-shaped specimens allowed the thickness of the different layers to be better controlled. The flat surface obtained also allowed the spectrophotometer to be more precisely used resulting in more reliable color measurements.¹⁶⁻¹⁸ Despite the influence of the layering technique^{19,20} and the porcelain veneer thickness^{5,19} on the intended shade, manipulative variables like firing temperatures,²¹⁻²⁴ condensation and powder/liquid ratios^{25,26} also influenced the color of the final restoration. For this reason, three specimens for each shade of each veneering system were fabricated. Small differences between specimens similarly layered might be considered acceptable and representative of the clinical reality. In the present study a uniform thickness of 1.0 mm of translucent porcelain on a 0.5 mm zirconia core was employed for all the specimens. The use of a pre-determined thickness allowed standardization to be achieved in order to quantify color differences and compare porcelain brands and shades. The 1.0 mm thickness was selected since this has been reported to be acceptable for porcelain translucency²⁷ and it is representative of the usual clinical conditions. The identification of a ΔE value for the "clinically acceptable differences" in shade matching is still controversial.⁷ In the present study, the value of $\Delta E = 3.3$ was selected.²⁸ On the basis of the selected value, a different behavior of the three tested ceramic veneering systems could be observed. The two-way ANOVA showed statistically significant differences ($P < 0.05$) among the tested ceramic systems. Based on these results, the application of different veneering materials to a set thickness applied on a given zirconia core resulted in significant color deviations from the target shade. Such color variations were observed in all the investigated shades (A2, A3 and A4 in the VITA Classical shade guide). The results are in agreement with a previous study⁶ in which porcelain systems for PFM restorations were investigated with the same methodology. These findings confirmed the role and the importance of the layer ratio in the ceramic layering procedure and consequently the need for clearer information. The thickness and the combination of ceramic layers have been shown to influence the final appearance of ceramic restorations both for PFM^{5,20,29-37} as well as for all-ceramic restorations.^{9-11,19,38} Dozic et al¹⁹ reported that for all-ceramic systems, small changes in thickness and shade of translucent porcelain layers can influence the final shade of the layered porcelain specimens. Shokry et al¹⁰ investigated the specific influences of the core and the veneering thickness on the appearance of layered

specimens. They found a correlation between the thickness ratio of core and veneer ceramics and the color of the restoration. Ozturk et al³⁸ reported that the color difference varied with respect to dentin ceramic thicknesses. Specifically for PFZ restorations, Lee et al⁹ investigated the effect of the combination of different veneering porcelains with different core materials, including zirconia, on the final color of the restorations. They found that different brands of zirconia core, even when linked to the Vita Classical shade guide, exhibited differences in color. Son et al¹¹ showed the effect of veneer ceramic on zirconia substrate (Lava), reporting that color changes of the layered ceramics varied by brand, shade and dentin porcelain thickness. They concluded that the final appearance of zirconia core ceramic restorations could be manipulated by varying the dentin porcelain thickness. On the basis of the reported literature and of the results of the present investigation, further studies are necessary to increase knowledge of veneering, particularly regarding the role of each single layer. In a recent study⁵ on PFM restorations about the influence of each porcelain layer on the color parameters of the restorations, it was reported that greater thicknesses of opaque dentin resulted in an increase in chroma, while a greater thickness of translucent dentin decreased the chroma of the restoration. Furthermore an increased thickness of translucent enamel resulted in a reduction in lightness and vice versa. It would be of interest to verify whether these findings can be replicated for zirconia veneered restorations. According to the results of the present study, it appears that there is a lack of information from the manufacturers on precise and scientifically based layering schemes to obtain a target shade. Success in shade reproduction with a ceramic system still seems to rely on a time-consuming trial-and-error process, rather than a color science driven layering protocol.

- a. Ivoclar Vivadent AG, Schaan, Liechtenstein.
- b. Vita Zahnfabrik, Bad Sackingen, Germany.
- c. Willi Geller International AG, Meiningen, Austria.
- d. Buehler, Lake Bluff, IL, USA.
- e. Beta, Milan, Italy.
- f. Systat Software Inc., San Jose, CA, USA.

Disclosure statement: The authors had no conflict of interest or relationship with the manufacturers of the products used in the present investigation.

Dr. Vichi is Research Professor, Dr. Fazi is a PhD student, Dr. Corciolani is Clinical Instructor, and Dr. Ferrari is Professor and Chair, Tuscan School of Dental Medicine, Department of Dental Materials and Fixed Prosthodontics of Siena, University of Florence and Siena, Italy. Dr. Louca is Senior Lecturer, Department of Continuing Professional Development, UCL Eastman Dental Institute, London, UK.

References

1. Preston JD. Current status of shade selection and color matching. *Quintessence Int* 1985;16:47-58.
2. Miller L. Shade matching. *J Esthet Dent* 1993;4:143-153.
3. Wee AG, Monaghan P, Johnston WM. Variation in color between intended matched shade and fabricated shade of dental porcelain. *J Prosthet Dent* 2002;87:657-666.
4. Douglas RD, Brewer JD. Variability of porcelain color reproduction by commercial laboratories. *J Prosthet Dent* 2003;90:339-346.
5. Corciolani G, Vichi A, Louca C, Ferrari M. Influence of layering thickness on the color parameters of a ceramic system. *Dent Mater* 2010;26:737-742.
6. Fazi G, Vichi A, Corciolani G, Ferrari M. Spectrophotometric evaluation of color match to VITA Classical shade guide of four different veneering porcelain systems for metal ceramic restorations. *Am J Dent* 2009;22:19-22.
7. Vichi A, Louca C, Corciolani G, Ferrari M. Color related to ceramic and zirconia restorations: A review. *Dent Mater* 2011;27:97-108.
8. Stevenson B, Ibbetson R. The effect of the substructure on the colour of samples/restorations veneered with ceramic: A literature review. *J Dent* 2010;38:361-368.
9. Lee YK, Cha HS, Ahn JS. Layered color of all-ceramic core and veneer ceramics. *J Prosthet Dent* 2007;97:279-286.
10. 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;95:124-129.
11. Son HJ, Kim WC, Jun SH, Kim YS, Ju SW, Ahn JS. Influence of dentin porcelain thickness on layered all-ceramic restoration color. *J Dent* 2010;38 Suppl 2:e71-77.
12. Corciolani G, Vichi A. Repeatability of colour reading with a clinical and a laboratory spectrophotometer. *Int Dent South Africa* 2006;8:62-70.
13. Clarke FJJ. Measurement of the color of the human teeth, Dental ceramics. In: Proceedings of the first international symposium on ceramics. 1983;441-488.
14. CIE (Commission Internationale de l'Eclairage). Colorimetry - Technical report. CIE pub. no. 15:2004. 3rd ed. Vienna: Bureau Central de la CIE; 2004; 18.
15. Groh CL, O'Brien WJ, Boenke KM. Differences in color between fired porcelain and shade guides. *Int J Prosthodont* 1992;5:510-514.
16. Seghi RR, Johnston WM, O'Brien WJ. Performance assessment of colorimetric devices on dental porcelains. *J Dent Res* 1989;68:1755-1759.
17. Wee AG, Kang EY, Johnston WM, Seghi RR. Evaluating porcelain color match of different porcelain shade-matching systems. *J Esthet Dent* 2000;12:271-280.
18. Kourtis SG, Tripodakis AP, Doukoudakis AA. Spectrophotometric evaluation of the optical influence of different metal alloys and porcelains in the metal-ceramic complex. *J Prosthet Dent* 2004;92:477-485.
19. Dozic 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;90:563-570.
20. Jarad FD, Moss BW, Youngson CC, Russell MD. The effect of enamel porcelain thickness on color and the ability of a shade guide to prescribe chroma. *Dent Mater* 2007;23:454-460.
21. O'Brien WJ, Kay KS, Boenke KM, Groh CL. Sources of color variation on firing porcelain. *Dent Mater* 1991;7:170-173.
22. Barghi N. Color and glaze: Effects of repeated firings. *J Prosthet Dent* 1982;47:393-395.
23. Barghi N, Goldberg J. Porcelain shade stability after repeated firing. *J Prosthet Dent* 1977;37:173-175.
24. Celik G, Uludag B, Usumez A, Sahin V, Ozturk O, Goktug G. The effect of repeated firings on the color of an all-ceramic system with two different veneering porcelain shades. *J Prosthet Dent* 2008;99:203-208.
25. Rosenstiel SF, Johnston WM. The effects of manipulative variables on the color of ceramic metal restorations. *J Prosthet Dent* 1988;60:297-303.
26. Zhang Y, Griggs JA, Benham AW. Influence of powder/liquid mixing ratio on porosity and translucency of dental porcelains. *J Prosthet Dent* 2004;91:128-135.
27. Brodbelt RH, O'Brien WJ, Fan PL. Translucency of dental porcelains. *J Dent Res* 1980;59:70-75.
28. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. *Dent Mater* 2004;20:530-534.
29. Douglas RD, Przybylska M. Predicting porcelain thickness required for dental shade matches. *J Prosthet Dent* 1999;82:143-149.
30. Jacobs SH, Goodacre CJ, Moore BK, Dykema RW. Effect of porcelain thickness and type of metal-ceramic alloy on color. *J Prosthet Dent* 1987;57:138-145.
31. Terada Y, Maeyama S, Hirayasu R. The influence of different thicknesses of dentin porcelain on the color reflected from thin opaque porcelain fused to metal. *Int J Prosthodont* 1989;2:352-356.
32. Terada Y, Sakai T, Hirayasu R. The masking ability of an opaque porcelain: A spectrophotometric study. *Int J Prosthodont* 1989;2:259-264.
33. O'Brien WJ, Johnston WM, Fanian F. Double-layer color effects in porcelain systems. *J Dent Res* 1985;64:940-943.
34. Antonson SA, Anusavice KJ. Contrast ratio of veneering and core ceramics as a function of thickness. *Int J Prosthodont* 2001;14:316-320.
35. Davis BK, Johnston WM, Saba RF. Kubelka-Munk reflectance theory applied to porcelain veneer systems using a colorimeter. *Int J Prosthodont* 1994;7:227-233.
36. Corciolani G, Vichi A, Goracci C, Ferrari M. Colour correspondence of a ceramic system in two different shade guides. *J Dent* 2009;37:98-101.
37. Corciolani G, Vichi A, Louca C, Ferrari M. Color match of two different ceramic systems to selected shades of one shade guide. *J Prosthet Dent* 2011;105:171-176.
38. 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.