

Spectrophotometric evaluation of color match to VITA classical shade guide of four different veneering porcelain systems for metal ceramic restorations

GIOVANNI FAZI, DDS, MS, ALESSANDRO VICHI, DDS, PhD, GABRIELE CORCIOLANI, DDS, MS & MARCO FERRARI, MD, DDS, PhD

ABSTRACT: Purpose: To determine by a spectrophotometric analysis the variations in color between the fabricated shade of four different porcelain systems and the intended shade when applied in a set thickness. **Methods:** Four porcelain systems (Duceram Kiss, VITA Omega, Wieland Reflex, Ivoclar IPS d.SIGN) for metal ceramic restorations were selected. Three disk-shaped (15 mm diameter, 0.3 mm thickness) specimens per group were made for three different shades of the A color scale of the Vitapan classical shade guide. On a Cr-Co alloy, 0.15 mm of porcelain opaque and 1.0 mm of translucent porcelain was applied. The porcelain stratification was executed according to the manufacturers' indications. The color measures were made by the clinical spectrophotometer Easyshade. **Results:** No statistically significant differences were found among the ceramic systems examined. The recorded differences in color between A2 porcelain disks and corresponding VITA shade tabs were closer (mean $\Delta E = 2.50$) than those recorded for shade A3 (mean $\Delta E = 3.84$) and shade A3.5 (mean $\Delta E = 3.94$) ($P < 0.05$). (*Am J Dent* 2009;22:19-22).

CLINICAL SIGNIFICANCE: When made based on the manufacturer's instructions, the four porcelain systems tested may fail to achieve clinically acceptable matching of the selected shade.

✉: Dr. Giovanni Fazi, Via A. Lamarmora 22, 50121 Florence, Italy. E-✉: fazi_90211@yahoo.com

Introduction

Color matching of a ceramic restoration to natural dentition remains a key factor in achieving optimal esthetic results in prosthetic dentistry. In clinical practice the color matching task is accomplished by the shade selection process, which starts by using a visual assessment or instrumental color analysis. Visual shade selection is the most common method of color determination. Several shade guides have been proposed by the manufacturers and by far the most used worldwide is the Vitapan classical.^a Once the target shade map is determined the laboratory should replicate this color by mean of a porcelain system that usually is correlated to the selected shade guide. The factors that have an influence on final color of dental porcelain include porcelain brand and batch, firing conditions, condensation technique, modeling liquid, substrate and porcelain thickness.

The manipulative variables of firing temperatures and condensation, as well as the choice of modeling liquid were found in a previous study¹ to have little influence on the final color of the restoration. The number of firings however is a potential source of color variations as documented,¹⁻⁷ but if the number of firings is limited to five, the effect is negligible.² Batch to batch variations were found to have a moderate influence on color.^{7,8} The substrate, meaning the alloy type of the metal ceramic restoration, is a potential source of color variation.⁹⁻¹⁵ An important source of variability of the color is the porcelain thickness as previously reported.^{6,10,13,16,17}

Preston¹⁸ identified as one of the major limits of the current shade-guide systems the fact that porcelains do not match the shade guides. Wide variations of color according to the porcelain brand have been documented.^{1,7,12,19} Customized shade tabs have been advocated to minimize this problem but so far the dental community has not embraced this procedure.²⁰

An additional difficulty of predicting the final color is rep-

resented by the need of having different layers of porcelain such as opaque, dentin and enamel.^{21,22} It is accepted that the opaque layer should be as thin as possible to mask the metal substructure and usually appears to be 0.10–0.15 mm.²³ In addition, the amount of translucent porcelain necessary to reproduce the color of the target shade should be at least 1.0 mm.^{10,12,23,24} Very limited information is available from the manufacturers or from the literature, on what the ideal proportion of dentin and enamel should be.

This study evaluated, by a spectrophotometric analysis, the variations in color between four dental porcelain systems and the target shades “A2, A3 and A3.5” of the shade guide Vitapan classical. The null hypothesis was that all porcelain systems would be able to clinically match the intended shade achieving $\Delta E \leq 3.7$.

Materials and Methods

In order to make an appropriate use of the porcelain systems, instructions regarding the proper layering were retrieved from the manufacturers' documentation of the porcelain systems. All the information available consisted of diagrams where the thickness of the different layers of opaque, dentin and enamel were calculated. The measures were calculated at 45% of the length of a central incisor starting from the incisal margin. Values were displayed in percentage and were used in the construction of the samples (Table 1).

In order to simulate metal ceramic restorations, disk-shaped specimens were preferred to tooth-shaped specimens previously employed.¹⁹ Disk-shaped specimens allowed a better control of the thickness of different layers and a flat surface was preferred in order to allow a more precise use of the spectrophotometer and obtain repeatable color measures.²⁵⁻²⁷ A diagram of the samples is presented in Fig. 1. A porcelain substrate was selected (Cr-Co alloy - Heraenium P^b). Metal disks 15 mm in diameter and 0.3 mm thick were fabricated using a cylindrical

Table 1. Porcelain systems selected for the study.

Porcelain system	Porcelain layer
Duceram Kiss	Opaque Dentin Incisal
Ivoclar IPS d.SIGN	Opaque Dentin Incisal
Vita Omega 900	Opaque Opaque dentin Dentin Incisal
Wieland Reflex	Opaque Dentin Incisal

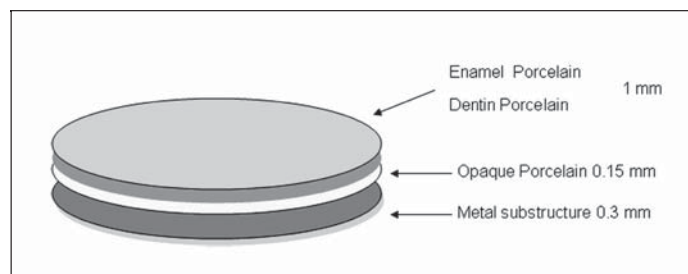


Fig. 1. Scheme of stratification of disk-shaped specimens.

custom made steel mold (Fig. 2). The device also allowed having a mold 15 mm in diameter where height could be adjusted and acted as a guide to produce calibrated layers. The cast metal specimens were adjusted with stones, airborne-particle abraded with 50 μ m aluminum oxide, cleaned with steam, and then oxidized according to the manufacturer guidelines.

Three different shades (A2, A3, A3.5) for four different ceramic systems were object of the present investigation. Ceramic systems were VITA Omega 900,^a Duceram Kiss,^c Wieland Reflex,^d and Ivoclar IPS d.SIGN^e obtaining a total of 12 combinations. For each group, three samples were fabricated for a total of 36 specimens (Table 1).

The metal specimen was inserted in the device and the same device was used in order to obtain calibrated layers of porcelain. A layer of 0.1 mm of porcelain opaque was first applied. Translucent porcelain, dentin and enamel were layered in the same manner according to the values obtained by the manufacturer diagrams as previously calculated (Table 2). The total amount of translucent porcelain was 1 mm in thickness. The use of 1.0 mm thickness is representative of the usual clinical conditions and has been accepted for porcelain translucency.²⁸ The layer thickness was evaluated after each firing and the necessary corrections were made by either grinding or adding porcelain. A digital caliper (1651 DGT^f) with a 10 μ m resolution was used for all the measurements.

Condensation procedures were executed manually in the same manner as routine laboratory work. All the specimens were fabricated by the same operator. The porcelains were fired according to the manufacturer's recommendations.

In VITA Omega 900 specimens, a 0.1 mm layer of opaque dentin was applied in addition to translucent dentin and enamel as recommended by the manufacturer. However, the total thickness of the porcelain was equal to 1.0 mm as were the other specimens.

Table 2. Percentages of dentin and enamel translucent porcelain calculated at 45% of the length of a central incisor starting from the incisal margin.

Porcelain system	Dentin porcelain	Enamel porcelain
VITA Omega 900	10% opaque dentin + 80% dentin	10%
Duceram Kiss	80%	20%
Wieland Reflex	80%	20%
Ivoclar IPS d.SIGN	50%	50%



Fig. 2. Custom made cylindrical device.



Fig. 3. Clinical spectrophotometer VITA Easyshade.

All the specimens were subjected to four firings. No glazing cycle was performed. The porcelain surface was not polished because the adopted spectrophotometer is designed to avoid the influence of specular reflection, so glazing and polishing do not interfere with the measurements.²⁹

Color of dental materials is expressed in "L*, a*, b*" coordinates according to the CIELab color space. "L*" value represents the brightness, "a*" value represents the redness or greenness and "b*" value represents the yellowness or blueness. The color difference of two objects can be calculated comparing the differences between respective coordinates applying the formula proposed by Clarke:³⁰

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

In the present study the threshold value of $\Delta E \leq 3.7$ for a clinical color match was adopted as suggested in the literature.³¹

Color measurements were made by a clinical spectrophotometer Easyshade^a (Fig. 3). The instrument has already stored the data for the Vitapan Classical shade guide.

The instrument utilizes a 20 Watt halogen stabilized tungsten filament lamp. The Easyshade probe contains multiple

Table 3. Delta E values recorded by the spectrophotometer.

Ceramic	Omega 900			Duceram Kiss			Ivoclar dSIGN			Wieland		
	A2	A3	A3.5	A2	A3	A3.5	A2	A3	A3.5	A2	A3	A3.5
ΔE	2.9	3.9	2.0	2.0	3.4	4.2	3.5	3.7	4.7	1.2	3.9	4.9
values	3.4	4.2	2.1	2.4	3.6	4.3	3.5	3.9	4.7	1.4	4.2	5.0
	2.9	3.9	2.0	2.0	3.5	4.0	3.2	3.5	4.6	1.6	4.4	4.8

receiver fiber optics spaced at different distances from the light source, coupled to two spectrometers, which varies the effective depth of the color measurement within a tooth or ceramic restoration. As a result, the path lengths of the light rays are different for the two spectrometers. The spectral resolution is 25 nm over the visible light range from 400 nm to 700 nm. The spectrophotometer makes up to 50 measurements per second.²⁹

Corciolani *et al*³² previously assessed the repeatability of color reading ability of the Vita Easyshade and as suggested the instrument was secured to a stand in order to have a repeatable position for the readings. Five readings were made for every sample and a mean was calculated.

Delta E values, calculated by the spectrophotometer according to the formula proposed by Clarke³⁰ were statistically analyzed. The normality of the distribution in the groups was preliminarily checked using the Kolmogorov-Smirnov test. Two one-way ANOVA tests were applied assuming first the values of ΔE as the dependent variable and the shade selected as factor and then the values of ΔE as the dependent variable and the ceramic system selected as factor. The level of significance was set at $P < 0.05$. Tukey HSD test was applied for post-hoc comparison where needed.

Results

The values recorded by the spectrophotometer are reported in Table 3. Values of ΔE ranged between 1.2 and 5.0. Shade clinical matching ($\Delta E \leq 3.7$) was recorded for shade A2 in all the ceramic systems, for shade A3 in Duceram Kiss and Ivoclar IPS specimens and for shade A3.5 only in Vita Omega 900 specimens. All the other specimens failed to achieve shade matching.

The means of ΔE values calculated for the ceramic system and for the shade are shown in Table 4. The means for the four ceramic systems were 3.03; 3.27; 3.92 and 3.49 regardless of the shades. VITA Omega 900 obtained the best average shade matching. However ANOVA analysis showed no statistically significant differences ($P > 0.05$) between the porcelain brands.

One-way ANOVA showed that the ceramic shade significantly influenced the ΔE values ($P < 0.05$). Post-hoc comparison among the ceramic shades further revealed that values of ΔE of A2 (a) shade were comparable and significantly better if compared to shades A3 (b) and A3.5 (b).

Discussion

This study compared the color differences of fired porcelain compared to the shade guide Vitapan Classical. The stratification of the porcelain was executed in accordance to the diagrams retrieved by the manufacturers' instructions for central incisors, calculated at 45% of the length of a central incisor starting from the incisal margin. For this study, it was

Table 4. Means of ΔE values horizontally according to the ceramic system and vertically according to the shade.

Ceramic system	Shade			Mean
	A2	A3	A3.5	
VITA Omega 900	3.07	4.00	2.03	3.03
Duceram Kiss	2.13	3.50	4.17	3.27
Ivoclar dSIGN	3.40	3.70	4.67	3.92
Wieland Reflex	1.40	4.17	4.90	3.49
Mean	2.50	3.84	3.94	
Significance	a	b	b	

decided to use flat disk-shaped specimens in order to provide uniform thicknesses of the ceramic layers. Tooth shaped specimens employed in other studies,¹⁹ allow light reflection similar to clinical conditions, but hardly allow uniform thicknesses of porcelain. It is well documented in the literature that thickness of porcelain is one of the main sources of shade mismatch.^{6,10,13,16,17} In the present study a uniform thickness of 1.0 mm was obtained for all the specimens. The use of a set thickness allows for a defined condition under which the color differences can be quantified and porcelain brands can be compared. The use of 1.0 mm thickness is representative of the usual clinical conditions and has been accepted for porcelain translucency.²⁸

Several studies^{31,33-36} provide information regarding clinical color-matching tolerance. Vichi *et al*³⁶ reported the value of $\Delta E < 1$ as not appreciable by the human eye. Johnston & Kao³¹ determined clinically acceptable shade matching in oral conditions for ΔE up to 3.7.

For shade A2 all the porcelain brands showed values of ΔE below or equal to 3.7 and therefore clinically acceptable. This result was also confirmed by one-way ANOVA test, where a statistically significant difference was found ($P < 0.05$). Post-hoc test assessed the closest color correspondence with standards for A2 shade (a) rather than A3 and A3.5 shades (b) (Table 4). Therefore, the null hypothesis must be rejected because only specimens in A2 shade for all ceramic systems, in A3 shade for Duceram Kiss and Ivoclar IPS and in A3.5 shade for Vita Omega 900 were able to clinically match the intended shade achieving $\Delta E \leq 3.7$, while all the other specimens failed to achieve shade matching.

The use of a layered porcelain (opaque, body and incisal) was preferred because of the similarity to the clinical condition. In previous studies^{21,22} double layer porcelain was found to produce differences in color when compared to single layer samples. Different porcelain systems seem to require different proportions in terms of thickness of porcelain layers. Such variation in adjunct to variation of powder content, is a great source of color variation.

One of the limitations of this type of investigation is the limited information available from the manufacturers regarding the amount of opaque, body and incisal porcelain necessary to obtain the desired shade. In the present study the stratification was based on the diagrams retrieved from the manufacturers' instructions, but it is unknown what the degree of accuracy of such diagrams is.

Future investigations should address other shades (B, C, and D) of the VITA scale, and establish if by varying the percentage

of incisal and body translucent porcelain, better shade matching can be achieved. The role in shade matching of opaque modifiers and opaque dentin should also be clarified.

According to the results of the present investigation, it may be concluded that the indications given from the manufacturer to help the technician to obtain the color match between the selected shade and the final restoration are very limited, and not sufficient to avoid color mismatch. Even if the right color selection is made, the fabrication of restoration color is still not a completely predictable procedure.

- a. Vita Zahnfabrik, Bad Sackingen, Germany.
- b. Heraeus Kulzer, Dormagen, Germany.
- c. DeguDent, Hanau, Germany.
- d. Wieland Dental, Pforzheim, Germany.
- e. Ivoclar Vivadent AG, Schaan, Liechtenstein.
- f. Beta, Milan, Italy.

Dr. Fazi and Dr. Corciolani are PhD students, Dr. Vichi is Clinical Professor, Department of Dental Materials, and Dr. Ferrari is Professor and Dean, School of Dentistry, University of Siena, Siena, Italy.

References

1. Rosenstiel SF, Johnston WM. The effects of manipulative variables on the color of ceramic metal restorations. *J Prosthet Dent* 1988;60:297-303.
2. Barghi N. Color and glaze: Effects of repeated firings. *J Prosthet Dent* 1982;47:393-395.
3. Barghi N, Goldberg P. Porcelain shade stability after repeated firing. *J Prosthet Dent* 1977;37:173-175.
4. Barghi N, Richardson JT. A study of various factors influencing shade of bonded porcelain. *J Prosthet Dent* 1978;39:282-284.
5. Ecker GA, Moser JB, Wozniak WT, Brinsden GI. Effect of repeated firing on fluorescence of porcelain-fused-to-metal porcelains. *J Prosthet Dent* 1985;54:207-214.
6. Jorgenson MW, Goodkind RJ. Spectrophotometric study of five porcelain shades relative to the dimensions of color, porcelain thickness, and repeated firings. *J Prosthet Dent* 1979;42:96-105.
7. O'Brien WJ, Kay KS, Boenke KM, Groh CL. Sources of color variation on firing porcelain. *Dent Mater* 1991;7:170-173.
8. Barghi N, Pedrero JA, Bosch RR. Effects of batch variation on shade of dental porcelain. *J Prosthet Dent* 1985;54:625-627.
9. Brewer JD, Akers CK, Garlapo DA, Sorensen SE. Spectrometric analysis of the influence of metal substrates on the color of metal-ceramic restorations. *J Dent Res* 1985;64:74-77.
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;57:138-145.
11. O'Neal SJ, Leinfelder KF, Lemons JE, Jamison HC. Effect of metal surfacing on the color characteristics of porcelain veneer. *Dent Mater* 1987;3:97-101.
12. Seghi RR, Johnston WM, O'Brien WJ. Spectrophotometric analysis of color differences between porcelain systems. *J Prosthet Dent* 1986;56:35-40.
13. Terada Y, Sakai T, Hirayasu R. The masking ability of an opaque porcelain: A spectrophotometric study. *Int J Prosthodont* 1989;2:259-264.
14. Woolsey GD, Johnson WM, O'Brien WJ. Masking power of dental opaque porcelains. *J Dent Res* 1984;63:936-939.
15. Crispin BJ, Seghi RR, Globe H. Effect of different metal ceramic alloys on the color of opaque and dentin porcelain. *J Prosthet Dent* 1991;65:351-356.
16. 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.
17. Douglas RD, Przybyska M. Predicting porcelain thickness required for dental shade matches. *J Prosthet Dent* 1999;82:143-149.
18. Preston JD. Current status of shade selection and color matching. *Quintessence Int* 1985;16:47-58.
19. Groh CL, O'Brien WJ, Boenke KM. Differences in color between fired porcelain and shade guides. *Int J Prosthodont* 1992;5:510-514.
20. Miller L. Organizing color in dentistry. *J Am Dent Assoc* 1987; Sp Is: 26E-40E.
21. O'Brien WJ, Fan PL, Groh CL. Color differences coefficients of body-opaque double layers. *Int J Prosthodont* 1994;7:56-61.
22. O'Brien WJ, Johnston WM, Fanian F. Double-layer color effects in porcelain systems. *J Dent Res* 1985;64:940-943.
23. Chiche GJ, Pinault A. *Esthetics of anterior fixed prosthodontics*. Chicago: Quintessence, 1994;97-113.
24. McLean J. *The science and art of dental ceramics. Vol. 1 The nature of dental ceramic and their clinical use*. Chicago: Quintessence, 1979;115-182.
25. Seghi RR, Johnston WM, O'Brien WJ. Performance assessment of colorimetric devices on dental porcelains. *J Dent Res* 1989;68:1755-1759.
26. 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.
27. 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.
28. Brodbelt RH, O'Brien WJ, Fan PL. Translucency of dental porcelains. *J Dent Res* 1980;59:70-75.
29. JTL Technology L. Vita Easyshade Technology. Bad Sackingen, Vita GmbH, 2003; 5-7.
30. Clarke FJJ. Measurement of the color of the human teeth. Dental ceramics. Proceedings of the First International Symposium on Ceramics. Chicago, Quintessence Pub Co Inc, 1983;441.
31. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. *J Dent Res* 1989;68:819-822.
32. Corciolani G, Vichi A. Repeatability of colour reading with a clinical and a laboratory spectrophotometer. *Int Dent SA* 2006;8:62-70.
33. Seghi RR, Hewlett ER, Kim J. Visual and instrumental colorimetric assessments of small color differences on translucent dental porcelain. *J Dent Res* 1989;68:1760-1764.
34. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. *Dent Mater* 1987;3:246-251.
35. Ragain JC Jr, Johnston WM. Minimum color differences for discriminating mismatch between composite and tooth color. *J Esthet Restor Dent* 2001;13:41-48.
36. 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.