



COLOR MATCH OF TWO DIFFERENT CERAMIC SYSTEMS TO SELECTED SHADES OF ONE SHADE GUIDE

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Statement of problem. There are no consistent indications given by dental manufacturers on how to layer ceramics to achieve a color match to a shade selected from a dental shade guide. The technique for ceramic layering relies primarily on the skill and experience of ceramists and is not easily predictable.

Purpose. The purpose of this study was to evaluate, using a clinical spectrophotometer, the ability to color match shades selected with the 3D-Master shade guide using 2 different ceramic systems.

Material and methods. Two ceramic systems were selected for this study, the VITA Omega 900 and VITA VM 13. For both systems, shades 2M3, 3M2, 4M2 of the VITA 3D-Master shade guide were selected. Thirty ceramic discs, 15 mm in diameter, were fabricated with different layer thickness ratios of opaque dentin, dentin, and enamel, maintaining a constant overall thickness. A clinical spectrophotometer (VITA Easyshade) was used for color comparison. The measured ΔE values were statistically analyzed with a 3-way ANOVA and the Tukey HSD test ($\alpha=.05$).

Results. The 3-way ANOVA showed that the ceramic system ($P<.001$), the selected shade ($P<.001$), and the layering scheme all significantly influenced the ΔE values ($P<.001$).

Conclusions. Both VITA VM 13 and VITA Omega 900 ceramic systems showed a color match with the shades 2M3, 3M2, and 4M2 of the VITA 3D-Master shade guide to be within the limits for clinical acceptability ($\Delta E \leq 3.3$). VM 13 showed a statistically better color match. The layering scheme influenced the definitive color of the restoration. (J Prosthet Dent 2011;105:171-176)

CLINICAL IMPLICATIONS

The ceramic systems evaluated, which are marketed according to the VITA 3D-Master shade guide, allowed color to be well controlled. VM 13 allows a better shade match than Omega 900.

Dental ceramic is widely used to replace natural tooth tissue because of its wear resistance, strength, toughness, and esthetics.¹ Several ceramic materials and systems are currently available for clinical use; there is not a universal material or system for all clinical situations.² Although it is possible to reproduce the natural

aspects of dental tissues with dental porcelain, esthetic excellence is not always easy to achieve, and the definitive color match of porcelain restorations to natural dentition remains a challenge.³⁻⁶

Tooth color is a combination of the optical properties of dentin, a relatively thick, opaque, and chro-

matic layer, and the optical properties of enamel, a relatively thin, more translucent, nearly achromatic layer. This layering gives the tooth its color and appearance and, ideally, should be replicated with dental porcelain. A relationship between translucency and thickness of the outer layers and color and reflectance of the inner lay-

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ers has been demonstrated, and these various aspects further challenge clinicians in achieving a good esthetic result.⁷ Dozic et al,⁸ in an *in vitro* study, reported that small changes in thickness and shade of the opaque and translucent porcelain layers can influence the definitive shade of metal-free ceramic restorations. In a recent study, Corciolani et al⁹ showed that variations in thickness of the various layers significantly influenced the definitive color of the metal ceramic restoration, and that these variations should be considered to obtain the desired shade, relative to the planned clinical thickness of the ceramic veneer. Several other factors have been reported to influence the definitive color of porcelain restorations, such as firing,¹⁰ glazing,¹¹ powder/liquid ratio,¹² and metal frameworks.¹³

During shade selection for a tooth, natural dental tissues are compared with the shade tabs of a shade guide. Although this color selection procedure has been the subject of several investigations,^{6,14-17} it is still considered to be nonscientifically based, and is therefore one of the weakest links in esthetic restorative dentistry. The introduction of the VITA 3D-Master shade guide (VITA Zahnfabrik, Bad Säckingen, Germany) significantly helped to simplify the shade selection process. The more regular distribution of the VITA 3D-Master shades in the CIE L*a*b* color space contributed to making the color selection procedure more reliable.^{18,19} In the CIE L*a*b* system, the L* value is the degree of lightness of an object, the a* value is the degree of redness or greenness, and the b* value is the degree of yellowness or blueness. Hammad et al²⁰ reported that the VITA 3D-Master shade guide is associated with a significant improvement in intrarater repeatability among general dentists when compared with the VITA Lumin Vacuum shade guide.

After a shade has been selected, it should be reproduced with ceramic, and Fazi et al²¹ showed that no consistent recommendations are provided by the manufacturers of dental

ceramics with respect to layering of materials to obtain the desired shade. Corciolani et al,²² in a recent study, compared ceramic discs produced using the Vitapan Classical shade guide and the VITA 3D-Master shade guide for shade selection, and reported that the VITA 3D-Master shade guide resulted in the best color matching, thus demonstrating that the ability to correctly reproduce the intended shade is shade-guide dependent.

No studies were identified by the authors in the dental literature comparing the ability of different ceramic systems to correctly match the desired shade of the VITA 3D-Master shade guide. Therefore, the purpose of this study was to test, by means of a clinical spectrophotometer, the ability of 2 different dental porcelain systems to correctly reproduce selected shades with reference to the VITA 3D-Master shade guide. The null hypothesis was that no difference would be found between the 2 ceramic systems in terms of correct reproduction of the selected color.

MATERIAL AND METHODS

Two ceramic systems were selected for this study: VITA Omega 900 (VITA Zahnfabrik, Bad Säckingen, Germany) and VITA VM 13 (VITA Zahnfabrik), both based on the VITA 3D-Master shade guide. A clinical spectrophotometer, VITA Easyshade (VITA Zahnfabrik), was used to measure color differences. To verify the color reliability of the 2 ceramic systems, 30 ceramic discs were fabricated with 2 different layering schemes for each ceramic system, for a total of 60 specimens. The overall thickness of the specimens remained constant throughout: a 1.3-mm-thick layer of ceramic was fired over a 0.3-mm-thick layer of a base metal alloy (Biomate-C; Silpo Srl, Rome, Italy). The total thickness was selected on the basis that the recommended degree of tooth reduction for metal ceramic restorations is 1.6 mm at the middle third of the tooth.²³

Autopolymerizing discs of acrylic

resin (DuraLay; Reliance Dental Mfg Co, Worth, Ill), 0.3 mm thick and 15 mm in diameter, were prepared in a cylindrical, custom-made, stainless steel mold. The mold allowed discs of fixed diameter (15 mm) and variable thickness to be fabricated. After placing the material into the mold, a glass plate was pressed onto the superficial layer to obtain a flat surface. Care was taken to avoid bubble formation within the resin. After polymerization, the resin specimen was extracted from the mold and placed in a refractory cast, which was then filled with investment (GC Stellavest; GC Europe NV, Leuven, Belgium) and placed in a burnout furnace (Ovomat 7; Manfredi Srl, Turin, Italy). At the end of the burnout cycle, the investment was moved to an induction casting machine (Enterprise; Jelrus Intl, Melville, NY), and a base metal alloy (Biomate-C; Silpo Srl) was cast. The resulting disc-shaped specimens were roughened with an airborne-particle-abrasion device (Sky-lab; Tecno-Gaz SpA, Parma, Italy) using 100- μ m AlO₂ particles (Ronvig Dental Mfg A/S, Dagaard, Denmark) at 6 bars of pressure. Flat disc specimens were used in this study to facilitate the process of obtaining controlled ceramic layer thicknesses, since Barrett et al²⁴ found no significant differences in shade matching accuracy between tabs and discs.

The shades selected for the study were 2M3, 3M2, and 4M2 from the VITA 3D-Master shade guide. Following the manufacturer's instructions, an opaque wash layer was applied first and fired in a ceramic furnace (VITA Vacumat 4000 Premium T; VITA Zahnfabrik), followed by the addition and firing of a second opaque layer. The first opaque dentin layer was then applied. By using the same mold that was used for fabricating the resin discs, it was possible to control the thickness of the ceramic layer applied before firing. After the application of each layer, the specimens were removed from the mold and fired following the manufacturer's instructions. Following application of the

first opaque dentin layer, a dentin layer was added and fired, followed by the enamel layer. Materials and batches used for the layering procedure are listed in Table I. Finally, each specimen was glaze fired according to the manufacturer's instructions. After each firing cycle, each layer was

measured with an electronic digital caliper (1651 DGT; Beta Utensili SpA, Sovico, Italy) with an accuracy of 10 μm . The thickness of each layer was considered acceptable for the study only when the variation in thickness was $\leq 20 \mu\text{m}$. The layering schemes (Table II) were selected on the basis

of recommendations from the manufacturer. Since Fazi et al²¹ found that a proper color match cannot be guaranteed by relying solely on layering schemes recommended by the manufacturers, and considering that ceramists work in a freehand manner and this could result in small differences in

TABLE I. Materials used for veneering procedure (all manufactured by VITA Zahnfabrik)

Layer	Shade	VITA Omega 900	Batch No.	VITA VM 13	Batch No.
Wash opaque	2M3	2M3 Opaque 9037	6203J	WO Wash Opaque Paste 359	7666
	3M2	3M2 Opaque 9313	6703		
	4M2	4M2 Opaque 9320	18730		
Opaque	2M3	2M3 Opaque 9037	6203J	OP2 Opaque Paste 352	7739
	3M2	3M2 Opaque 9313	6703	OP3 Opaque Paste 353	21780
	4M2	4M2 Opaque 9320	18730	OP4 Opaque Paste 354	10920
Opaque dentin	2M3	2M3 Opaque Dentine 9033	11690	2M3 Base Dentine 040	7516
	3M2	3M2 Opaque Dentine 9343	20260	3M2 Base Dentine 046	24780
	4M2	4M2 Opaque Dentine 9350	18730	4M2 Base Dentine 053	23300
Dentin	2M3	2M3 Dentine 9053	7999	2M3 Dentine 070	7468
	3M2	3M2 Dentine 9373	7654	3M2 Dentine 076	7737
	4M2	4M2 Dentine 9380	26650	4M2 Dentine 083	7698
Enamel	2M3	EN2 Enamel 9072	15200	ENL Enamel 191	7933
	3M2				
	4M2	EN4 Enamel 9074	26870	END Enamel 192	12660

TABLE II. Layering schemes used to fabricate ceramic specimens

Specimen		Shade	LS	Alloy	Opaque	Opaque Dentin	Dentin	Enamel	Definitive Thickness
VM 13	Omega 900								
1 - 5	31 - 35	2M3	1	0.30 mm	0.15 mm	0.45 mm	0.50 mm	0.20 mm	1.30 mm
11 - 15	41 - 45	3M2							
21 - 25	51 - 55	4M2							
6 - 10	36 - 40	2M3	2	0.30 mm	0.15 mm	0.35 mm	0.70 mm	0.10 mm	1.30 mm
16 - 20	46 - 50	3M2							
26 - 30	56 - 60	4M2							

LS, layering scheme

layering, 2 different layering schemes were evaluated.²²

The color measurements were performed with the clinical spectrophotometer VITA Easyshade (VITA Zahnfabrik). The repeatability of color readings and use of this clinical spectrophotometer for research purposes were previously assessed.^{9,25} The VITA Easyshade consists of a base unit and handpiece. The color measurements were made by fixing the instrument on a stand, since in a previous study it was shown that this arrangement resulted in a higher repeatability than freehand use.²⁵ All of the measurements were performed while keeping the tip of the spectrophotometer 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 guides (VITA Zahnfabrik), has the color coordinates of each shade of the Vitapan Classical and VITA 3D-Master shade guides stored in its memory. In “Restoration” mode, the instrument measures the color coordinates of the porcelain disc, and then compares these color coordinates with the stored data. The VITA Easyshade calculates the differences for lightness (the perception by which white objects are distinguished from gray objects and light-colored from dark-colored objects), chroma (the aspect of color in the Munsell color system by which a specimen appears to differ from a gray of the same lightness or brightness, and which corresponds to saturation of the perceived color), hue (the attribute of color perception by means of which an object is judged to be red, yellow, green, etc), and ΔE (the distance between points representing colors in the color space having rectangular coordinates).²⁶ These differences are calculated by the spectrophotometer according to the CIE standards.²⁷ Even if lightness,

chroma, and hue are individually important to clarify the differences between the data stored in the device and the data measured from the specimens, ΔE is the most important parameter for calculating color differences,²⁷ and for this reason, in the present study, ΔE values were statistically analyzed.

Having verified the normal distribution of the ΔE data according to the Kolmogorov-Smirnov test ($P=.077$) and the homogeneity of the group variances using the Levene test ($P=.821$), a 3-way analysis of variance (ANOVA) was used to determine the significance of the differences in shade match recorded for the groups. Delta E was considered to be the dependent variable, and ceramic system, shade, and layering scheme were the factors. Statistical software (SPSS 16.0; SPSS, Inc, Chicago, Ill) was used for statistical analysis. The Tukey Honestly Significant Difference (HSD) test was used to make multiple comparisons ($\alpha=.05$).

TABLE III. VITA Easyshade color evaluation for VITA VM 13 and for VITA Omega 900 ceramic systems. Mean Δ values (SD) are indicated

Shade	LS	Ceramic	ΔE	ΔL	ΔC	ΔH	Significance*
2M3	1	VM 13	0.98 (0.08)	0.56 (0.17)	-1.06 (0.21)	0.02 (0.13)	A
		Omega 900	0.88 (0.08)	0.44 (0.17)	0.60 (0.12)	-0.76 (0.95)	A
	2	VM 13	1.40 (0.12)	1.40 (0.12)	-0.04 (0.05)	0.48 (0.04)	B
		Omega 900	1.94 (0.09)	1.66 (0.15)	0.92 (0.19)	0.16 (0.05)	C
3M2	1	VM 13	1.06 (0.08)	0.05 (0.11)	-1.66 (0.18)	0.12 (0.04)	A
		Omega 900	1.76 (0.05)	0.70 (0.34)	1.20 (0.25)	-1.88 (0.19)	C
	2	VM 13	1.48 (0.08)	0.36 (0.11)	-1.28 (0.26)	-0.14 (0.09)	B
		Omega 900	1.48 (0.04)	1.14 (0.24)	0.98 (0.04)	-0.86 (0.09)	B
4M2	1	VM 13	0.96 (0.09)	-0.68 (0.13)	-0.26 (0.09)	-1.62 (0.04)	A
		Omega 900	1.90 (0.07)	1.14 (0.17)	-1.80 (0.12)	-0.92 (0.08)	C
	2	VM 13	1.42 (0.08)	-0.88 (0.16)	-0.88 (0.04)	-1.68 (0.04)	B
		Omega 900	0.96 (0.11)	-0.26 (0.09)	0.38 (0.18)	-2.24 (0.09)	A

*Different uppercase letters indicate significant differences when ΔE means of interaction ceramic system $\times$ shade $\times$ layering scheme were compared using Tukey HSD test ($P<.05$).

LS, layering scheme; ΔE , general error; ΔL , difference in lightness; ΔC , difference in chroma; ΔH , difference in hue

TABLE IV. Three-way ANOVA for shade match

Dimension	df	Sum of Squares	Mean Square	F	P
Ceramic	1	1.093	1.093	154.4	<.001
LS	1	0.542	0.542	76.4	<.001
Shade	2	0.262	0.131	18.5	<.001
Ceramic × LS	1	0.888	0.888	125.4	<.001
Ceramic × shade	2	0.049	0.025	3.5	.04
LS × shade	2	2.509	1.254	177.1	<.001
Ceramic × LS × shade	2	2.686	1.343	189.6	<.001

LS, layering scheme

RESULTS

Table III reports the color values measured with the VITA Easyshade spectrophotometer for VITA VM 13 and VITA Omega 900. Lower ΔE values mean a closer color match. The 3-way ANOVA (Table IV) revealed that the ceramic system significantly influenced the ΔE values ($P<.001$). Specifically, regardless of the layering scheme, VM 13 (mean of $\Delta E=1.22$) had significantly lower ΔE values than VITA Omega 900 (mean of $\Delta E=1.49$).

The layering scheme was a significant factor for ΔE values ($P<.001$). The Tukey HSD test for pairwise comparisons revealed that the overall ΔE values were lower for the LS1 (mean of ΔE , 1.26) than for the LS2 (mean of ΔE , 1.47) (Table III). The shade significantly influenced the ΔE values ($P<.001$). The Tukey test revealed that the ΔE values for 2M3 shade (mean of ΔE , 1.30) and for 4M2 shade (mean of ΔE , 1.31) were lower than for 3M2 shade (mean of ΔE , 1.45). The interaction between ceramic system, shade, and layering scheme was found to be significant ($P<.001$), and the results from the Tukey HSD test, subsequently used for pairwise comparisons, are shown in Table III.

DISCUSSION

The null hypothesis that no difference would be found to exist between the 2 ceramic systems with respect to correctly matching the selected color was rejected, since the VITA VM 13 ceramic resulted in a significantly closer color match when compared with the VITA Omega 900 ceramic ($P<.001$).

Despite the availability of information concerning dental ceramic manufacturing, the importance of layering to achieve the best color match is often not addressed with a scientific rationale,¹ and the problem is often managed subjectively, relying on the skill and experience of the individual ceramist involved. For the present study, 2 different layering schemes were selected. They were slightly different to evaluate the possible influence that variations in layering may have on color matching.²² The 2 layering schemes differed from each other with respect to the ratios of the base/opaque dentin, dentin, and enamel layers. When means were compared, the layering scheme was found to have a significant influence ($P<.001$). The closest shade match was achieved for the LS1 (in this scheme, the ratio between base/opaque dentin and dentin was 1:1, and the thickness of the enamel layer was 0.20 mm), rather than for the LS2 (in which 2 parts of dentin were layered upon 1 part of base/opaque dentin at a ratio of 1:2, and the thickness of the enamel was 0.10 mm) (Table III).

The 2 ceramic systems evaluated in this study are both based on the VITA 3D-Master shade guide. In a previous study performed by the same authors,²² it was found that the Omega 900 ceramic system (VITA Zahnfabrik) in the VITA 3D-Master exhibited a closer match in color than the same ceramic system in Vitapan Classical. With reference to the acceptability and perceptibility tolerance of shade mismatch in the clinical setting, Douglas et al²⁸ found that the predicted difference at which 50% of dentists could perceive a color difference (50/50 perceptibility) was 2.6 ΔE units, and the predicted difference at which 50% of the restorations would be remade due to color mismatch (clinically unacceptable color match) was 5.5 ΔE . Vichi et al²⁹ reported 3 different intervals for distinguishing color differences of composite resins. Delta E values of less than 1 unit were regarded as not appreciable by the human eye; ΔE values greater than 1 and less than 3.3 units were considered appreciable by skilled operators, but clinically acceptable; and ΔE values greater than 3.3 were considered perceivable by untrained observers, and for that reason, not acceptable. On the basis of this last classification, the values obtained in the present study are considered clinically acceptable, as analysis of the values obtained from the VITA Easyshade spectrophotometer (Table

III).

III) showed that all of the specimens have mean ΔE values below 1.96.

Even though all measured ΔE values were below the clinical acceptability threshold, the 2 tested ceramic systems behaved differently. Analyzing the results of the Tukey HSD test in Table III, the closest match in color occurred with VITA VM 13 (mean of ΔE , 1.22) compared to the Omega 900 ceramic (mean of ΔE , 1.49). The analysis of the interaction between ceramic system, layering scheme, and shade ($P < .001$) showed that, for the VM 13 ceramic system, no differences were found between the 3 shades tested (2M3, mean of ΔE , 0.98; 3M2, mean of ΔE , 1.06; 4M2, mean of ΔE , 0.96) when evaluating VM 13-LS1. This trend was also confirmed by the analysis of the 3 shades of VM 13-LS2 (2M3, mean of ΔE , 1.40; 3M2, mean of ΔE , 1.48; 4M2, mean of ΔE , 1.42) (Table III). With the VITA Omega 900 ceramic, the selected shade significantly influenced the ΔE values. Considering the Omega 900-LS1 level, the specimens layered in the 2M3 shade (mean of ΔE , 0.88) had a closer shade match when compared with the specimens layered in the 3M2 shade (mean of ΔE , 1.76) and in the 4M2 shade (mean of ΔE , 1.90). A significant interaction was also found when analyzing the Omega 900-LS2 level: the specimens layered in the 4M2 shade (mean of ΔE , 0.96) resulted in a closer shade match than specimens layered in 3M2 (mean of ΔE , 1.48) and in 2M3 (mean of ΔE , 1.94).

Despite this trend, the limited number of selected shades is a limitation of this study. Another limitation is that the measured differences, even if instrumentally detectable, statistically significant, and visually perceivable by trained operators, are of magnitudes below the threshold reported for clinical acceptability ($\Delta E \leq 3.3$). For this reason, the findings of this study may be primarily relevant for research purposes. The outcome of this study confirms the importance of understanding the behavior of each ceramic system and its influence on achieving the closest color match.

CONCLUSIONS

Within the limitations of this study, both the VITA VM 13 and VITA Omega 900 ceramic systems in the VITA 3D-Master shade guide showed differences compared to the intended shade, within the limits of clinical acceptability. The VITA VM 13 ceramic resulted in a closer color match. The layering scheme significantly influenced the definitive color of the restoration.

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