Clinical Color Match of Porcelain Visual Shade-Matching Systems

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ABSTRACT

Background: Accuracy of the total color replication process has not been clinically evaluated for various porcelain visual shade-matching systems.

Purpose: The purpose of this study was to evaluate the final color replication process of three porcelain visual shade-matching systems. Subjects' natural dentition was compared with laboratory-fabricated individualized porcelain shade tabs.

Materials and Methods: Shade matches of 10 subjects' incisors were obtained using three different porcelain visual shade-matching systems. Commercial laboratories fabricated one corresponding individualized porcelain shade tab for each incisor per visual shade-matching system selection. Color-match evaluations of the fabricated individualized porcelain shade tabs to the corresponding teeth were completed by prosthodontists' consensus and by subjects' self-evaluation using the US Public Health Service criteria. Statistical analysis was carried out on the combined evaluations with logistic regression and the Generalized Estimating Equation for repeated measures.

Results: The Vitapan 3D Master/Omega 900 system (Vident Inc., Brea, CA, USA) was significantly more likely than the Vita Lumin Vacuum/VMK 68 system (Vident Inc.) to obtain a clinically acceptable color match (odds ratio [OR] = 6.31; 95% CI = 1.24–32.07). The likelihood of obtaining a clinically acceptable color match through subjects' self-evaluation was found to be significantly higher compared with prosthodontists' consensus (OR = 2.75; 95% CI = 1.27–5.94).

Conclusions: Within the limits of this preliminary study, significant differences in clinical acceptability were seen between the color matches of the fabricated individualized porcelain shade tabs from different systems and subjects' central incisors. Subjects' range of acceptability was much broader compared with that of the prosthodontists in assessing the color match of the fabricated porcelain shade tabs.

CLINICAL SIGNIFICANCE

The use of certain porcelain visual shade-matching systems may result in a clinically acceptable color match of the final restoration more readily than the use of other systems. Color-match evaluation of final restorations should be accomplished through a consensus between prosthodontists and patients, given the difference in thresholds of acceptability.

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The ultimate goal of the restorative dentist is to restore a missing tooth structure to its natural form, function, and appearance at an acceptable level so as to positively impact the patient's self-esteem.[1] A clinically successful color match is one of the most important aspects of an esthetic dental restoration.

The color replication process for dental porcelain is composed of a shade-selection phase followed by a shade-duplication phase. Shade selection can be accomplished through either visual assessment or instrumental color analysis. Duplication of the selected shade is accomplished during the fabrication of the final restoration (Figure 1).

Concerns regarding the color replication process of porcelain crowns to their adjacent natural dentition are validated by evidence from clinical studies evaluating porcelain crowns in the area of color matching.[2–5] Traditional porcelain-fused-to-metal crowns were found to be mismatched in color (clinically acceptable or unacceptable mismatch) compared with the adjacent teeth over 60% of the time.[3,5] Newer esthetic, all-porcelain crowns were mismatched nearly 45% of the time. Results from these retrospective studies may even be underestimated given that laboratory remakes and extrinsically stained crowns were not taken into consideration. For instance, crowns that were grossly mismatched (clinically unacceptable) in color may have been remade subsequently by the laboratory prior to clinical delivery. Also, it is known that porcelain crowns exhibiting a mild color mismatch can be improved with the application and firing of extrinsic stains. However, these extrinsic stains can be brushed away within 10 to 12 years of normal toothbrushing with a common dentifrice.[6] Thus, concerns regarding the accuracy of the total color-replication process for porcelain crowns appear to be warranted.

The shade-replication process of three porcelain shade-matching systems (Vita Lumin Vacuum/Vita VMK 68, Vident Inc., Brea, CA, USA; Vitapan 3D Master/Vita Omega 900, Vident Inc.; and Shade-Eye-EX/Vintage Halo, Shofu Dental Corporation, Portland, OR, USA) has been evaluated previously.[7] Individualized shade tabs were fabricated by a dental student to replicate the color of the three porcelain shade-matching systems for 10 extracted teeth. Three dental evaluators using the US Public Health Service (USPHS) criteria did not find significant differences among the three systems.[8] However, limitations of the study, including the use of nonvital extracted teeth and inexperienced personnel (ie, a dental student), may have invalidated the results. Nonvital teeth show less saturation than do vital teeth, owing perhaps to the influence of the surrounding oral tissues.[9] The use of experienced laboratory technicians for the fabrication of the final restoration may improve the external validity of studies evaluating the color-replication process of porcelain systems. Evaluations by dental personnel who would have stringent acceptability criteria may also have negated any differences in this particular study.[7]

The current preliminary study improved on those limitations by comparing the use of various porcelain visual shade-matching systems in a clinical scenario with vital teeth. The use of three different commercial laboratories to fabricate the final individualized porcelain shade tabs and the use of two different color-match evaluations (prosthodontists' consensus and subjects' self-evaluation) were employed.

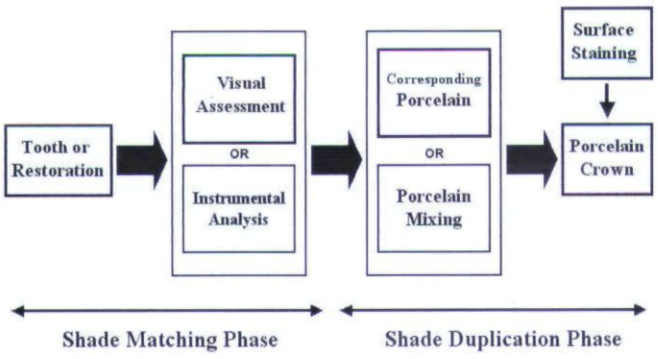

Figure 1. Color replication process for porcelain crowns.

The purpose of this in vivo preliminary investigation was to evaluate the final color-replication process of three porcelain visual shade-matching systems with vital human teeth. The hypothesis for this study was that the final color shade match between the subjects' natural dentition and the corresponding selected, laboratory-fabricated individualized porcelain shade tabs would differ among the three different porcelain visual shade-matching systems when evaluated using the USPHS criteria.

MATERIALS AND METHODS

Two prosthodontists obtained the shade match of 10 subjects' left maxillary central incisors in a color-corrected viewing booth (D65 lighting; Macbeth Spectra Light, New Windsor, NY, USA) using three porcelain visual shade-matching systems: (1) Vita Lumin Vacuum/VMK 68, (2) Vitapan 3D Master/Omega 900, and (3) Ivoclar Chromascop/Classic (Ivoclar Vivadent, Amherst, NY, USA). The commercial laboratories fabricated one porcelain shade tab for each subject per shade-matching system. The fabricated individualized porcelain shade tabs were evaluated for color match to the corresponding natural teeth in the viewing booth by two prosthodontists and by the subjects using the USPHS criteria (Table 1).[8] The experimental design is diagrammed in Figure 2.

Ten human subjects (one male and one female subject in each of the following five age groups: 19–28 yr, 29–38 yr, 39–48 yr, 49–58 yr, and 59–68 yr) were recruited for the study from within the College of Dentistry. Eligibility requirements included that subjects be at least 18 years of age with all of their natural upper anterior teeth present and free of any dental restorations or excess staining. A dental student recruited the subjects and obtained the subjects' consent for this study. The protocol (no. 00H0261) for the study was approved by the university's institutional review board.

Shade-Matching Phase

The three visual shade-matching procedures on all maxillary left central incisors were carried out as recommended by the respective porcelain visual shade-matching systems. Shade matching with the three different systems was performed in random order on each subject. The manufacturers' recommendations on the use of the shade guides were followed precisely during the study.

Visual shade matching was performed in a viewing booth with color-corrected D65 lighting by two prosthodontists; they determined the shade separately and then came to a consensus to obtain the selected shade. The prosthodontists who carried out the shade matches were found not to have any color deficiencies according to the American Optical Company Hardy-Rand-Ritter test.[7] The shade guides used were recommended by the respective porcelain visual shade-matching systems: (1) Vita Lumin Vacuum, (2) Vitapan 3D Master, and (3) Ivoclar Chromascop.

After the shades of the central incisors were selected, 35 mm slides (Fujichrome Sensia 100, Fuji Photo Film U.S.A., Inc, Valhalla, NY,

TABLE 1. DEFINITIONS OF USPHS CRITERIA FOR CLINICAL COLOR EVALUATION.

Questions	Answer	Code	Clinical Terminology Used in Manuscript	Terminology Used in the Analysis
Is there a mismatch in color, shade, and/or translucency between the restoration and the adjacent tooth structure?	No	Alfa	Match	Clinically acceptable
Is the mismatch between restoration and adjacent tooth structure outside the normal range of tooth color, shade, and/or translucency?	No	Bravo	Clinically acceptable mismatch	Clinically acceptable
	Yes	Charlie	Clinically unacceptable mismatch	Clinically unacceptable

Adapted from Cvar JF and Ryge G.[8]
USPHS = US Public Health Service.

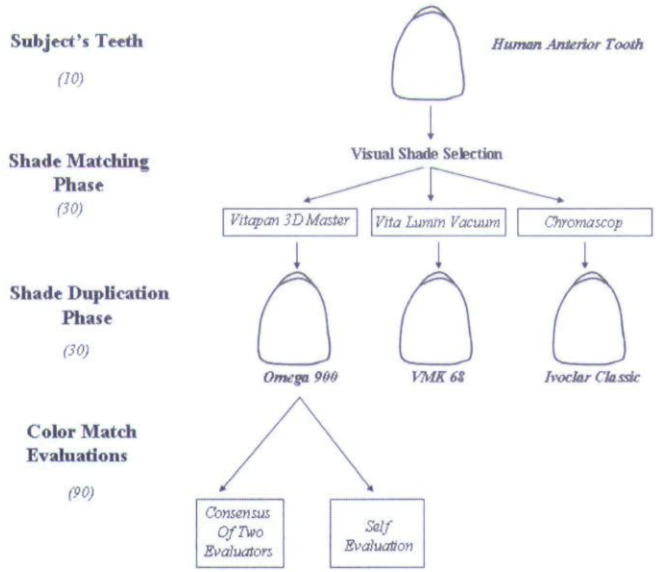

Figure 2. Flow chart of experimental design.

USA) were taken of each subject's left maxillary central incisor with the determined shade tab (Figure 3). A diagram indicating areas where incisal porcelain should be placed was also drawn for each subject (Figure 4).

Shade-Duplication Phase

The shade obtained for each subject's left maxillary central incisor during the shade-matching phase was used to prescribe the porcelain buildups on individual "blank" shade tabs (Individual Shade Guide Kit, Vident, Inc.). The three corresponding porcelain systems were used for fabrication of the porcelain shade tabs with respect to the porcelain shade-matching systems: (1) Vita VMK 68 porcelain system for the Vita Lumin Vacuum shade guide, (2) Vita Omega 900 porcelain system for the Vitapan 3D Master shade guide, and (3) Classic porcelain system for the Ivoclar Chromascop shade guide. Only one individualized porcelain shade tab was fabricated per porcelain color-matching system per subject. A total of 30 individualized porcelain shade tabs were fabricated.

Requests were sent to three different dental laboratories around the region to fabricate the individualized porcelain shade tabs. The commercial laboratories were selected based on the type of porcelain system that they used for their porcelain crown fabrication. The laboratories were sent a package containing blank shade tabs (Vident, Inc.), the specific shades selected, a 35 mm slide of the selected tooth and shade tab (see Figure 3), and a diagram elaborating the incisal translucency of the specific tooth (see Figure 4) for each subject. The laboratories also received specific instructions to fabricate the individualized porcelain shade tabs similar to the way they would fabricate porcelain-fused-to-metal crowns, with approximately similar dentin thickness (≈1 mm), shaped and glazed. Laboratories were specifically requested not to use any external stains to improve the color match of the tabs or even to verify that the color of the fabricated individualized porcelain shade tabs were similar to the intended shade.

Color-Match Evaluation of the Porcelain Shade Tabs

The 30 individualized porcelain shade tabs were labeled and

Figure 3. One subject's tooth and matched shade tab.

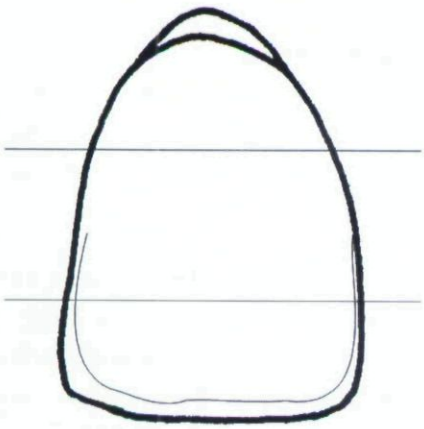

Figure 4. Incisal translucency sketch for one subject's tooth.

grouped according to the respective subjects. The tabs were then masked to ensure blindness in the color-match evaluation process. Color-match evaluations were made of the three fabricated individualized porcelain shade tabs to the respective subject's left maxillary central incisor (see Figure 2) by the consensus of two prosthodontists (PC) and by each subject's self-evaluation (SE) in a D65 lighting booth using the USPHS criteria. Color-match evaluations were categorized based on the following dictated ratings: match, mismatch/acceptable, or mismatch/unacceptable (see Table 1).

Statistical Analysis

One subject was removed from the study owing to bleaching of the teeth during the period of enrollment in the study. For analysis, *match* and *mismatch/acceptable* categories were combined and named *clinically acceptable*. The *mismatch/unacceptable* category was renamed *clinically unacceptable*. *Clinically acceptable* and *clinically unacceptable* were used as nominal variables. Predictor variables were gender, age group, evaluation (combined PC and SE), and the guides (3D Master, Lumin, and Chromascop).

The USPHS data were analyzed using logistic regression to model the color-match evaluation agreement. Because this model included repeated measures, the Generalized Estimating Equation was employed. All calculations were done using the SAS statistical program (9th ed, SAS Institute Inc, Cary, NC, USA).

RESULTS

Results for the percentage of clinically acceptable and clinically unacceptable matches for each porcelain shade-matching system and evaluation type (PC and SE) are elaborated in Figure 5. For the combined evaluations, the percentage of clinically acceptable matches was highest for Vitapan 3D Master (55%), followed by Chromascop (35%), and finally Vita Lumin Vacuum (20%). Results of SEs differed in that the percentages of clinically acceptable matches were similar for Chromascop (60%) and Vitapan 3D Master (50%), with Vita Lumin Vacuum at 30%. Professional evaluation results showed a distinct preference for porcelain shade tabs fabricated by the Vitapan 3D Master/Omega 900 system (60%) to produce a clinically acceptable match over the Vita Lumin Vacuum/VMK 68 and Chromascop/Classic systems, each with 10% clinically acceptable matches.

Overall, the odds of procuring a clinically acceptable color match using Vitapan 3D Master/Omega 900 system were found to be significantly higher (odds ratio [OR] = 6.31; 95% CI = 1.24–32.07) compared with Vita Lumin Vacuum/VMK 68 system (p = .026). The odds of obtaining a clinically

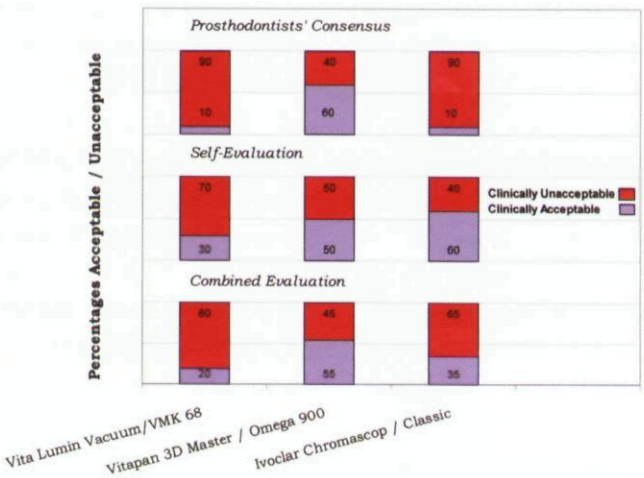

Figure 5. Percentage of acceptable/unacceptable shade matches for porcelain visual shade-matching systems.

acceptable color match between the natural dentition and corresponding selected, laboratory-fabricated individualized porcelain shade tabs with the subjects' SEs were found to be significantly higher than with the prosthodontists' consensus (OR = 2.75; 95% CI = 1.27–5.94) (p = .0099).

DISCUSSION

Results of this preliminary clinical study showed significantly improved outcomes for the Vitapan 3D Master/Omega 900 porcelain visual shade-matching system in obtaining clinically acceptable color matches of the fabricated individualized porcelain shade tabs compared with the results of a previous in vitro study that found similar but not significant results for the Vitapan 3D and Shade Eye-EX systems.[7] Cost and time constraints, the small sample size of this preliminary study, and lack of subject randomization warrant that these results be interpreted cautiously as they may not be generalized to the entire population.

The use of experienced laboratory technicians for the fabrication of the individualized porcelain shade tabs may also pose some challenges. Douglas and Brewer's study of variability of porcelain color reproduction by dental laboratories showed a significant difference among five laboratories reproducing the Vita A3.5 shade tab (Vita Lumin, Vacuum) with metal-ceramic crowns.[10] The average color differences between the shade tabs and 10 fabricated crowns were significantly different at two sites (middle and incisal) for the five laboratories. Moreover, 90% of the average color differences between the two sites and five laboratories were found to be perceptibly different, and 50% did not obtain a clinically acceptable color match as determined under intraoral conditions. In this study, the use of the three different commercial laboratories may have confounded the results. Random assignment of the shade tabs to the laboratories or the use of one experienced technician to fabricate the shade tabs of all three systems are two possible alternatives to compensate for this challenge.

Another factor in the design that improves the clinical relevance but perhaps limits the external validity of the results is the use of clinically relevant techniques to improve communication to the laboratory technician,[11] such as use of 35 mm slide, the inclusion of the selected shade tab, and a graphic representing the required incisal translucency. This objective was to have the fabricated individualized porcelain shade tab closely resemble the tooth being matched in terms of shape and incisal translucency. It was a concern that if the individualized shade tab did not resemble the tooth, this would be distracting to the evaluators during the color-match evaluation in the study. It is unfortunate that the extent of the use of such recommended communication techniques is not known. Not providing such added information may have resulted in a better control of the possible variables, such as the ability of the laboratory technician to modify the porcelain to improve the intended shade match that is shown on the 35 mm slide.

Finally, the shade of the teeth evaluated may have changed during the time from the initial shade selection to the final color-match evaluation. It is known that only one of the subjects used bleaching products, but many subjects may have used dentifrice products that have minor bleaching properties, creating a change in the tooth shade.[10,12] Variations in color may also be attributed to metal influence through the metal-ceramic porcelain tabs.[13–15]

Despite these limitations, the results of this preliminary study provide insights to evaluate current visual porcelain shade-matching systems. It is not surprising that the consensus reached by the two prosthodontists was more critical than the subjects' SE. The prosthodontists have more training in color matching and understand what the ideal color replication should be in the oral environment. In contrast, subjects usually view teeth during a wide smile and do not constantly critique the dentition in the oral environment.

Even though the Vita Lumin Vacuum shade guide has been a popular and familiar guide used for many years, the color-match evaluations of the final individualized porcelain shade tabs did not perform well. This study evaluated the total color-

replication process of the three porcelain visual shade-matching systems, that is, the shade-matching and the shade-duplication phases. The low matches obtained in this study could be due to multiple factors, including the fact that color evaluations of the individualized shade tabs were made of the central incisor, which is in an area of high esthetic demands. The technicians were also requested not to use any artistic methods to improve the shade of the individualized shade tab, that is, surface stains or porcelain mixing. The Vitapan 3D Master/Omega 900 system performed much better than the Vita Lumin Vacuum/VMK 68 system. Perhaps the greater number of shades (26) in the 3D Master/Omega 900 system compared with only 16 shades in the Vita Lumin Vacuum/VMK 68 system contributed to the results. The positive results of the Vitapan 3D Master/Omega 900 system could also be attributed to claims by the manufacturers that the shades in this new system are better distributed in the tooth color space.[16]

Performing a clinical trial on a greater number of subjects with the use of actual porcelain-fused-to-metal crowns and randomization of laboratories would provide external validity to the use of these systems in private practice.

CONCLUSIONS

Within the limits of this preliminary study, the newer visual porcelain shade-matching system, Vitapan 3D Master/Omega 900, demonstrated a better shade-matching ability than the traditionally used Vita Lumin Vacuum/VMK 68. Subjects demonstrated a wider range of acceptability with regard to the shade matching of porcelain shade tabs than did prosthodontists.

DISCLOSURE AND ACKNOWLEDGMENTS

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