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CLINICAL RESEARCH

# A comparison between visual, intraoral scanner, and spectrophotometer shade matching: A clinical study

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## ABSTRACT

**Statement of problem.** Visual shade matching is subjective and a cause of concern for clinicians. Different measurement devices have been developed to assist in tooth color selection and to achieve better esthetic results. However, consensus is lacking as to which method of tooth shade selection provides more predictable results.

**Purpose.** The purpose of this clinical study was to compare the reliability of different visual and instrumental methods for dental shade matching.

**Material and methods.** Visual shade matching was performed by 3 experienced clinicians using 2 different shade guides (VITA Classical A1-D4 and VITA Toothguide 3D-MASTER with 29 tabs; VITA Zahnfabrik) with and without the aid of a light-correcting device (Smile Lite; Smile Line). An intraoral scanner (TRIOS; 3Shape A/S) and a spectrophotometer (VITA Easyshade Advance 4.0; VITA Zahnfabrik) were also used for color shade matching. The instrumental methods were repeated 3 times to determine repeatability. Shade-matching sessions for each method were performed under controlled lighting on the middle third of the maxillary right central incisor of 28 participants. The Fleiss' kappa statistical test was used to assess the reliability of each method. The weighted kappa statistical test was used to assess the agreement between the shades matched by different methods ($\alpha$=.05).

**Results.** Instrumental methods were more accurate than visual methods. The best performance was found for the intraoral scanner configured for the 3D-MASTER scale (Fleiss' kappa value of .874) and for the spectrophotometer configured for the VITA Classical scale (Fleiss' kappa value of .805). The best visual shade-matching method was the VITA Classical scale associated with the light-correcting device (Fleiss' kappa value of .322). The Classical scale without the light-correcting device showed the poorest reliability (Fleiss' kappa value of .177) ($P$<.05).

**Conclusions.** Instrumental methods for color shade matching were more reliable than the visual methods tested. (J Prosthet Dent 2019;121:271-5)

Tooth shade matching is mostly a trial and error method influenced by clinician proficiency, visual fatigue, and surrounding light source.[1] Accurate color reproduction with a restorative material is challenging.[2-7] Furthermore, patient expectations for the outcomes of the restorative treatment are often high.[8-10] Shade selection in dentistry can be performed by using both visual methods with a shade guide and instrumental methods such as using a spectrophotometer, a colorimeter, and, more recently, an intraoral digital scanner.[1,4,11]

The human eye is efficient in detecting small differences in tooth color.[12,13] However, communicating such differences to the dental technician is complex.[12] The wide range of different tones, translucency, opacities, and characterizations of a tooth may not be detected. Visual shade matching is subject to variables such as age, sex, experience, type of scale used, different degrees of light exposure, eye fatigue, and physiological variables such as color deficiency, which may lead to inconsistencies.[14-21]

Light-correcting devices are available to minimize lighting interference and to allow neutral clarity to assist

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## Clinical Implications

The reliability of the instrumental methods compared strongly suggests the supplementary use of shade-matching instruments to visual shade guides in clinical practice.

the visual method of shade matching.[6,22] An example is a handheld lamp with light-emitting diode–based technology with a color temperature of 5500K.[23] The device has a light source similar to that of the internal light source of the most commonly used dental spectrophotometer.[23] The device corrects for varying light conditions such as the time of day, season of the year, and type of light sources in the dental office.[23] Such devices reduce reflected light to allow for a more accurate assessment of dental translucency and therefore provide more reliable visual shade-matching results.[6]

Portable intraoral spectrophotometers are also available to assist tooth shade matching. The spectrophotometer's handpiece illuminates the tooth with a 6500K light for color matching and displays the results based on visual shade guides. Intraoral scanners have recently been introduced in dental practice, and some are able to capture colored images and make a clear distinction between soft and hard tissue structures.[1] Shade color results from intraoral scanners are also based on visual shade guides.

Studies comparing both visual and instrumental methods have mostly shown better results for spectrophotometers than for visual shade guides.[4,24] Color-measuring devices are therefore expected to enhance the accuracy of shade matching as well as the interpretation and fabrication of dental restorations.[4]

Few clinical studies have investigated the use of digital color images obtained using an intraoral digital scanner for shade selection as compared with other available methods.[4,23] Therefore, the purpose of the present study was to evaluate the reliability of visual (different shade guides with and without the aid of a light-correcting device) and instrumental (spectrophotometer and intraoral scanner) methods for tooth shade matching. The null hypothesis was that no significant differences would be found in the reliability of repeated visual and instrumental shade matching.

## MATERIAL AND METHODS

The study protocol was approved by the Ethics Committee of the Fluminense Federal University School of Dentistry (approval number: 1.388.597). All participants received verbal and written information about the study and signed an informed consent before inclusion. Three experienced clinicians (W.P., R.T., W.F.L.) with superior color-matching competency (ISO TR 28642:2011)[25] participated in the study. Each clinician had been screened for color deficiencies using the Ishihara plates.[26] Exclusion occurred when 5 or more incorrect answers were found. The study sample included 28 volunteers aged between 20 and 40 years with a sound right maxillary central incisor and without any severe enamel anomaly or pigmentation.[6]

Visual shade matching was carried out separately by each clinician at the same time of the day and in the same dental office, with walls of neutral colors and a window with natural lighting and under a light source with a color temperature of 5500K.[24] Each patient was seated on the dental chair, and each examiner performed the shade-matching procedure with only a dental assistant present to record the selected tooth shade. Each examiner was blinded to the shade color selected by the other examiners. Shade matching was performed on the middle third of each participant's maxillary right central incisor by using 2 shade guides (VITA Classical A1-D4 and VITA Toothguide 3D-MASTER with 29 tabs; VITA Zahnfabrik) with and without the aid of a light-correcting device (Smile Lite; Smile Line) (Fig. 1).

Instrumental shade matching was performed by a previously calibrated examiner (W.P.) using an intraoral scanner (TRIOS; 3Shape A/S) and a spectrophotometer (VITA Easyshade Advance 4.0; VITA Zahnfabrik) (Fig. 2). Three short-term instrumental shade assessments were made on each participant's right maxillary central incisor. Both the instruments were configured to provide results by using the 2 visual shade guides tested (VITA Classical A1-D4 and VITA Toothguide 3D-MASTER). A statistical analysis was performed using the IBM SPPS Statistics, v24 statistical software (IBM Corp). The Fleiss' kappa statistical test for multiple measurements was used to assess method reliability. The weighted kappa statistical test assessed the agreement between the shades matched by the different methods tested. The sample size needed to achieve a power of 90% with a significance level of 5% was 26 participants (critical z=1.96).

## RESULTS

Twenty-eight participants were enrolled to account for possible exclusions and dropouts. Table 1 presents the reliability of the different shade-matching methods. The instrumental methods showed a higher reliability than the visual methods. The highest Fleiss' kappa values were found for the intraoral scanner configured for the VITA 3D-MASTER shade guide (.874) and for the spectrophotometer configured for the VITA Classical shade guide (.805). Visual shade matching without a light-correcting device was the least reliable method for

**Figure 1.** Shade matching with light-correcting device (Smile Lite).

**Figure 2.** Shade matching with spectrophotometer (VITA Easyshade Advance 4.0; VITA Zahnfabrik).

tooth shade matching (VITA Classical: .177; VITA 3D-MASTER: .206). The use of a light-correcting device increased the reliability of the visual shade method.

Tables 2 and 3 show the agreement between the shades matched by each method. The highest agreement for the Vita Classical shade guide was found between the shades matched by the visual shade method and by the visual shade method associated with the light-correcting device (weighted kappa value of .725), followed by the agreement between the intraoral scanner and the spectrophotometer (weighted kappa value of .546) (Table 2). The highest agreement for the Vita 3D-MASTER shade guide was also found for the visual shade method and for the visual shade method associated with the light-correcting device (weighted kappa value of .515) (Table 3).

## DISCUSSION

The results found in this study support rejection of the tested null hypothesis because significant differences were found in reliability between repeated visual and instrumental shade matching. Instrumental methods were more reliable than visual methods. The best performance was found for the intraoral scanner configured for the 3D-MASTER scale (Fleiss' kappa value of .874) and for the spectrophotometer configured for the Classical scale (Fleiss' kappa value of .805). Interpretation of the Fleiss' kappa values ranges from .20 to .40 (fair), .40 to .75 (intermediate to good), and above .75 (excellent).[4]

The VITA Classical scale is currently the most taught and used shade guide.[4,12] The results of this study showed that the VITA Classical scale was the least reliable shade guide tested (Fleiss' kappa value of .177), followed by the VITA 3D-MASTER shade guide (Fleiss' kappa value of .206). This shows the difficulties faced by clinicians with esthetic restorations. The poor results found for visual shade matching in this study are consistent with those of earlier studies.[2,4,5,21] Training for tooth shade selection could affect the results and lead to more predictable outcomes for visual shade-matching methods.[4,8,9,13,24]

A light-correcting device (Smile Lite) was used with the visual shade guides and provided some improvement in tooth color selection. This is consistent with an earlier study[22] that found better shade-matching ability with the use of a light-correcting device. The same study[22] also reported that the results were not further improved after attaching a polarization filter to the light-correcting device.

Agreement between the shades matched by each method was higher when the VITA Classical guide was used. The highest agreement was found between visual shade matching and visual shade matching with a light-correcting device (weighted kappa value of .725). The same was found for the VITA 3D-MASTER shade guide (weighted kappa value of .515). This was somewhat expected because the same raters were responsible for each shade matching for both the groups. The agreement was poor when the instruments were configured for the VITA 3D-MASTER shade guide. This could be due to the greater shade availability than that of the VITA Classical shade guide—the higher shade availability led to a higher variance in the shades that were matched by each

**Table 1.** Method reproducibility for tooth shade matching (Fleiss' kappa statistical test)

| Shade-Matching Methods | Fleiss' Kappa |
|---|---|
| Intraoral scanner (VITA Classical) | .639 |
| Spectrophotometer (VITA Classical) | .805 |
| Visual shade matching (VITA Classical) | .177 |
| Visual shade matching (VITA Classical+light-correcting device) | .322 |
| Intraoral scanner (VITA 3D-MASTER) | .874 |
| Spectrophotometer (VITA 3D-MASTER) | .700 |
| Visual shade matching (VITA 3D-MASTER) | .206 |
| Visual shade matching (VITA 3D-MASTER+light-correcting device) | .306 |

**Table 2.** Agreement between shades matched (weighted kappa statistical test) by each method according to VITA Classical shade guide

| | Intraoral Scanner | Spectrophotometer | Visual Shade Matching | Visual Shade Matching+Light-Correcting Device |
|---|---|---|---|---|
| Intraoral scanner | 1.000 | .546 | .342 | .491 |
| Spectrophotometer | .546 | 1.000 | .158 | .279 |
| Visual shade matching | .342 | .158 | 1.000 | .725 |
| Visual shade matching+light-correcting device | .491 | .279 | .725 | 1.000 |

**Table 3.** Agreement between shades matched (weighted kappa statistical test) by each method according to VITA 3D-MASTER shade guide

| | Intraoral Scanner | Spectrophotometer | Visual Shade Matching | Visual Shade Matching+Light-Correcting Device |
|---|---|---|---|---|
| Intraoral scanner | 1.000 | .152 | -.151 | -.082 |
| Spectrophotometer | .152 | 1.000 | .041 | -.015 |
| Visual shade matching | -.151 | .041 | 1.000 | .515 |
| Visual shade matching+light-correcting device | -.082 | -.015 | .515 | 1.000 |

method tested (both visual and instrumental). The poor color-matching agreement found between the different methods was also reported in a previous study.[10] The authors also suggested that instrumental shade matching seems not to reflect human shade-matching perception.[10]

In this study, instrumental methods were more reliable than visual methods. This is consistent with an earlier study that suggested the use of color-matching instruments as a supplementary tool to improve the outcome of esthetic restorations.[4] Other studies have suggested that tooth color selection using instrumental methods has greater agreement and effectiveness than visual methods.[6,14] Another study stated that using an intraoral scanner could not be the primary method for tooth color selection because of differences in color parameters with the colorimeter.[1] Advantages of instrumental shade matching include more uniform communication between professionals and more accurate color selection.[6,14] Such devices give control over external light conditions, and the photo-optic measurement allows color quantification.[6,14] However, the high cost of the equipment still limits its more widespread use in clinical practice.[19]

A limitation of the present study was that no time limit was set for each shade-matching process. Eye fatigue could therefore have occurred. The examiners were instructed to rest their eyes on a neutral color background[22] to minimize fatigue and error. A future study could limit the time for each shade-matching session to better understand the influence of the time limit in the shade-matching process. Another limitation is that no standard scanning method has been suggested for shade matching with a digital scanner, and variables such as scan angle and distance, light source, and experience of the operator could be hard to control.[1] Future studies could test different clinical situations with different scanning angles and distances to clarify this issue.

## CONCLUSIONS

Based on the findings of this clinical study, the following conclusions were drawn:

1. Instrumental methods for tooth color selection were more reliable than the visual method.
2. The VITA 3D-MASTER shade guide showed a better interrater agreement than the VITA Classical shade guide.
3. The use of a light-correcting device associated with the visual shade guides provided some improvement in interrater agreement.

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