SCIENTIFIC ARCHIVES OF DENTAL SCIENCES (ISSN: 2642-1623)

Volume 2 Issue 12 December 2019

Research Article

Evaluation of Accuracy of Conventional Visual, Spectrophotometric and 3D Scanning Methods by Using Two Shade Guide Systems

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Received: October 24, 2019; **Published:** November 13, 2019

Abstract

Aim of the Study: The aim of this study was to compare conventional visual shade determination, an intraoral spectrophotometer and 3D scanner to determine accuracies and interrater agreement of these three methods.

Methods: In the visual method, 59 examiners (29 of them were specialists in prosthodontics and conservative dentistry and 30 were dental students) with normal color vision calibrated by control shade tabs taken from the two shade guides (VITAPAN Classical and VITAPAN 3D Master). Each tab was matched 3 times to determine repeatability of visual examiners. The spectrophotometric and 3D scanning shade matching was performed by one trained examiner under the same standardized test conditions using an intraoral spectrophotometer and 3D scanner with three repetitions for each tab.

Results: Results revealed that 3D scanning (81.4%) and spectrophotometric (77.8%) methods had greater accuracy than the visual method (38.7%). Also, the 3D scanner and spectrophotometer, exhibited significantly better interrater agreement as compared to the visual method without any significant difference between two instrumental methods. Besides, results revealed that specialists had greater accuracy (48.1%) than the dental students (33.4%).

Conclusion: 3D scanning and spectrophotometric methods for color shade matching was more reliable than the visual methods tested.

Keywords: Accuracy; Reliability; Shade Guide; Spectrophotometer; 3D Scanner

Introduction

Accurate color matching in restorative dentistry is key success factor in aesthetics [1]. Colors may have different distribution under varying light sources result in different color perception. This phenomenon is known as metamerism [1]. The color of natural tooth is the result of not only light reflected from the enamel surface but also light scattered and reflected from both enamel and dentine [2]. Several factors can influence the perception of tooth color including the light source, the object being viewed and the observer viewing the object [2]. There are two ways of assessing tooth color. The most popular method for shade matching is the visual method using tooth form shade tabs [3-5]. VITAPAN Classical and VITAPAN 3D-Master are two most popular shade guides in market [4]. Visual method may be affected by variables such as external light conditions, operator experience, eye fatigue, and color blindness [5]. Other disadvantages of visual method including in-

adequate range of available colors in the shade guides and lack of consistency between dentists and laboratory technicians in using the shade guides lead to equivocal findings on tooth color matching [6].

Electronic color-measuring devices have been recently introduced as tools with the ability to improve the accuracy and reliability of shade selection which include spectrophotometers, colorimeters, and digital camera systems with corresponding software [7,8]. These devices basically consist of a detector, signal conditioner and software that processes the signal to make the data usable in the clinic or laboratory [7]. Dental shade matching was introduced to market to overcome imperfections and inconsistencies of traditional shade matching [8].

The spectrophotometer can be used consistently to measure the natural tooth color accurately regarding to a specific color and is adaptable to other shade matching systems [9]. It measures the amount of light energy reflected from an object at 1-25 nm intervals along the visible spectrum [10].

Intraoral scanners were introduced in order to increase patient comfort and improve dentist lab communication [8]. Also, clinicians are given the opportunity to work in a virtual environment and to improve the diagnosis, planning, and treatment of cases by the recent development of digital technology in dental practice [7,8].

The results of investigations of the relationship between visual and instrument shade matching have been controversial [11]. Comparison between visual and instrumental shade matching methods has been unique subject in dental research topics [12]. Some studies reported better results for dental spectrophotometer than visual methods [6,13-15]. In contrast, other studies [2,16,17] introduced electronic color-measuring devices as instruments with no consistency in measuring color parameters or matching teeth to shade systems compared to visual methods.

Aim of the Study

The aim of this study was to evaluate and compare the differences in color selection between visual technique using Vita Classical and Vita 3D-Master shade guides and the data recorded by a 3D scanner and spectrophotometer.

Methods

This study was conducted by using two sets each of shade guide system including VITAPAN Classical™ and VITAPAN 3D-Master™ (Vita Zahnfabrik, Bad Sackingen, Germany). One set was assigned to determine the target control tabs while the conventional visual shade matching was performed using second set of each shade guide system.

This study was conducted in a double-blinded design in that the identity of target control tabs were concealed from participants of shade matching and the person who recorded the observations.

59 examiners were trained to use the equipment participated in the visual shade matching process written and verbally. 29 of them were specialists in prosthodontics and conservative dentistry and 30 were dental students. The spectrophotometric (VITA Easyshade™, Vita Zahnfabrik, Bad Sackingen, Germany) and intraoral scanning (Sirona, Bensheim, Germany) shade matching was performed by one independent examiner using an intraoral spectrophotometer and scanner. All participants were subjected to the lshihara color blindness test in order to determine the visual acuity.

Nine target control tabs were chosen from one set of each shade guide systems including five shade tabs from the VITAPAN 3D-Master and four shade tabs from the VITAPAN Classical. These were then obscured by tape and labelled. The matching was done under standardized lighting conditions, a 60 × 60 cm panel type LED light source with 4000 K color temperature was used to illuminate the room. Area of the room was 5 m^2 (2 × 2.5m) and the ceiling height was 3.5m. An A4 sheet of gray card was used to rest the subject's eyes between shade assessments. Examiners were asked to look at it for 15 seconds to avoid color fatigue. The examiners read out their answers which were recorded by another person who was also blinded from the identity of the target control tabs.

Each of 59 examiners were asked to repeat visual method of shade matching of nine target control tabs 3 times and in the same way was asked one examiner in spectrophotometric and intraoral scanning methods. Thus, a total of 1647readings were recorded (1593 for visual method, 27 for spectrophotometric and 27 for intraoral scanning methods). An explanation was given to each examiner how to use the shade guides before doing the visual selection whether they had used them previously or not. Afterwards, the ex-

aminers looked at the control tabs and decided what was the best shade match. The volunteers were allowed to pick up the shade tabs with no time limitation.

The Spectrophotometer was used in the same windowless room, under the light of 4000K color temperature according to the manufacturer's instructions. It was calibrated after each tab by placing the probe in the ceramic calibration chamber on the device. The spectrophotometric shade matching was performed by one examiner with three repetitions for each tab. For the shade matching reference point the spectrophotometer was set on Vita classical and Vita 3D-Master.

The intraoral scanner under the same conditions as mentioned above and one examiner with three repetitions was used in this study. The scanner was calibrated for color selection prior each scan. All data were expressed in color codes corresponding to Vita classical and Vita 3D-Master.

Chi-square test was used to analyze the differences in proportion between examiners and shade guide systems. Also, the difference in accuracy of examiners for the visual methods was compared (specialist and dentistry students). Furthermore, in order to capture the degree of *agreement* between *raters*, as well as the relation between ratings, Cohen's kappa was used. Data were analyzed using SPSS version 20 software (IBM Co., Chicago, IL, USA) at the significance level of 0.01.

Results

The percentage of correct answers in 3 D scanning and spectrophotometric methods was more than visual method and difference was statically significant ($p < 0.01$) (Table 1). However, no significant difference was reported between scanner and spectrophotometer ($p = 0.623$). In the visual method of shade selection, the VITAPAN 3D-Master shade guide proved to be better giving 442 correct responses out of the total 885 responses (Figure 1). While VITAPAN 3D-Master shade guide was more accurate with visual method, both shade guides have showed great accuracy with the 3D scanner and spectrophotometer with no significant difference between them.

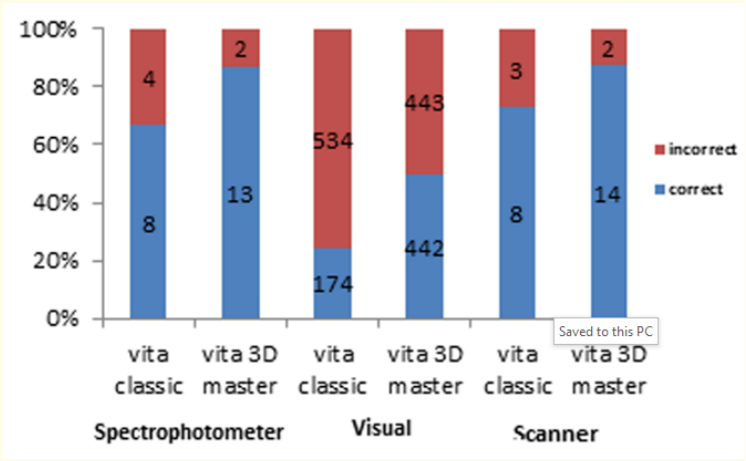

Figure 1: *Comparison of accuracy between visual, 3D scanning and spectrophotometric methods.*

Method	Correct	Incorrect	Test statistic χ^2	df	P
Visual	616 (38.7%)	977 (61.3%)	17.019	1	0.000
3D scanner	22 (81.4%)	5 (18.6%)			
Spectrophotometer	21 (77.8%)	6 (22.2%)			

Table 1: *Comparison of accuracy between shade matching methods.*

In the 3D scanning and spectrophotometric methods no significant difference was found between Vita 3D-Master and Vita classical (p = 0.123).

The level of interrater agreement was determined for all methods and shade guides (Table 2). The 3D scanning and spectrophotometric methods showed an excellent level of interrater agreement, irrespective of the shade guide used. The agreement was poor for the visual method while using the VITAPAN 3D- Master and VITAPAN Classical shade guides was employed.

There was significant difference in the accuracy between groups of examiners (p < 0.01). Results revealed that specialists had greater accuracy (48.1%) than the dental students (33.4%) (Table 3 and Figure 2).

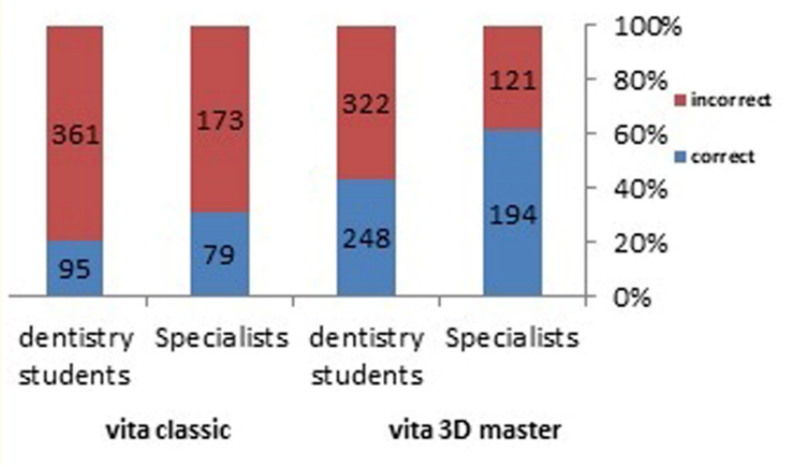

Figure 2: *Comparison of accuracy of visual shade matching between specialties and dental students.*

Method	Shade guide	Statistic	Value	Strength of agreement
Visual	Vita 3D master	Cohen's kappa	0.050	Poor
Visual	Vita classic	Cohen's kappa	0.143	Poor
3D scanner	Vita 3D master	Cohen's Kappa	0.638	Excellent
3D scanner	Vita classic	Cohen's Kappa	0.702	Excellent
Spectrophotometer	Vita 3D master	Cohen's kappa	0.623	Excellent
Spectrophotometer	Vita classic	Cohen's kappa	0.714	Excellent

Table 2: *Comparison of interrater agreement among different methods.*

Group	Correct	Incorrect	Test statistic 2%	df	p
Specialists	273 (48.1%)	294 (51.9%)	33.353	1	0.000
Dental student	343 (33.4%)	683 (66.6%)			

Table 3: *Comparison of accuracy of visual shade matching between specialties and dentistry students.*

Discussion

The present study compared the accuracies of visual and instrumental (3D scanner and spectrophotometer) shade matching using two shade guide systems (VITAPAN Classical and VITAPAN 3D-Master) which made this study unique and comprehensive comparing to previous studies in this field. The results of this study disagreed the previous idea that the visual method in shade matching was more reliable than instrumental methods [2,16,17]. Instrumental color analysis offers a potential advantage over visual color determination because instrumental reading is less affected by external factors, can be quantified, and are more rapidly reproducible [8,11,18].

For visual shade selection, the light used in the environment is an important factor [19]. So, it is difficult to prepare a standard and identical place regarding to light source for all clinicians. However, as spectrophotometers operate with an internal light source, the measurement surface is illuminated with this standardized light during capture [20,21]. Hence, instrumental results are more reliable [14,15,22,23].

Nowadays, the Vita classical shade guide is most used shade guide [14,15,23,24]. Liberato., *et al.* [25] reported that the Vita classical scale was the least reliable shade guide followed by the Vita 3D-Master. Their findings were same as our study which found Vita-3D Master more reliable with the higher interrater agreement compared to Vita classical. The Vita 3D-Master system uses 36 shade tabs compared to the Vita Lumin 16 shade tabs, which may account for the difference in results [26]. Besides, several important characteristics have been improved with the Vita 3D-Master shade guide: the lightness range is broader, more chromatic tabs are included, the shade tabs are more uniformly spaced, the hue range is extended in the direction of the reddish spectra, group division is better, the overall tab arrangement is much better compared with the Vitapan classical shade guide, however certain disharmony still exists [27,28].

Our study resembling many previous researches in this field [10,11] found the poor results for visual shade matching compared to 3D scanning and spectrophotometric method. Also, in our study, the highest agreement was found for 3D scanning and spectrophotometric methods. Advantages of instrumental shade matching include more uniform communication between dentists and laboratory technicians as well as accurate color selection [28,29]. However, these instruments are not available for all dentists worldwide in clinical practice due to high cost and advance technology [5].

Culic., *et al.* [10] have shown that the digital intraoral scanner could not be used as an accurate method of shade selection, considering significant differences in shade tab codification with the spectrophotometer. In contrast, in our study, no significant difference was found between 3D scanner and spectrophotometer shade guides. It might be related to the fact that making the standard conditions *in vivo* is harder than in the laboratory.

In our study, accuracy refers to the exact reproduction of the masked shade tab using either the instrumental method or the visual method. This study showed that the 3D scanning (81.4%) and spectrophotometric (77.8%) methods of shade matching were more accurate than the visual method (38.7%) irrespective of the shade guide used.

Another purpose of this study was to evaluate the effect of clinical experience level on the shade matching accuracy. Results showed that specialists had greater accuracy (48.1%) than the dental students (33.4%). This study supports previous researches which reported that the clinical experience and education on shade matching ability is effective [5,30-33]. Moreover, the results of Gasparik., *et al*. [34], in 2014 indicated that clinical experience has no effect on shade matching ability. In the mentioned study, it might happen because undergraduate dental students and general dentists with 5 - 6 years of clinical experience had participated in the study while in the present study, dental students were compared with specialists in prosthodontics and conservative dentistry who had more experience and knowledge than general dentists.

Limitation of the Study

Limitation of our study was that no time limit was set up for each shade-matching process. Future studies can focus on new generations of electronic color-measuring devices such as digital scanners and spectrophotometers as well as conditions can affect accuracy of shade matching methods.

Conclusion

A comparison of accuracy between shade matching methods revealed that there was significant difference between the 3D scanning and spectrophotometric methods compared to the visual

method. This study has shown that specialist produced more accurate results than the dental students. Also, in visual method Vita 3D master shade guide was more accurate than the Vita classic shade guide.

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