Comparison of accuracies of an intraoral spectrophotometer and conventional visual method for shade matching using two shade guide systems

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Abstract

Background and Objectives: This *in vitro* study compared the shade matching abilities of an intraoral spectrophotometer and the conventional visual method using two shade guides. The results of previous investigations between color perceived by human observers and color assessed by instruments have been inconclusive. The objectives were to determine accuracies and interrater agreement of both methods and effectiveness of two shade guides with either method.

Methods: In the visual method, 10 examiners with normal color vision matched target control shade tabs taken from the two shade guides (VITAPAN Classical™ and VITAPAN 3D Master™) with other full sets of the respective shade guides. Each tab was matched 3 times to determine repeatability of visual examiners. The spectrophotometric shade matching was performed by two independent examiners using an intraoral spectrophotometer (VITA Easyshade™) with five repetitions for each tab.

Results: Results revealed that visual method had greater accuracy than the spectrophotometer. The spectrophotometer; however, exhibited significantly better interrater agreement as compared to the visual method. While VITAPAN Classical shade guide was more accurate with the spectrophotometer, VITAPAN 3D Master shade guide proved better with visual method.

Conclusion: This *in vitro* study clearly delineates the advantages and limitations of both methods. There were significant differences between the methods with the visual method producing more accurate results than the spectrophotometric method. The spectrophotometer showed far better interrater agreement scores irrespective of the shade guide used. Even though visual shade matching is subjective, it is not inferior and should not be underrated. Judicious combination of both techniques is imperative to attain a successful and esthetic outcome.

Key Words: Accuracy, dental shade matching, repeatability, shade guide, spectrophotometer

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INTRODUCTION

Shade determination for direct and indirect restorations has always been a challenging aspect of esthetic dentistry. Visual shade determination using commercially available shade guides, although the most frequently applied method, is considered highly subjective. It may be affected by variables such as external light conditions, experience, eye fatigue, and color blindness.[1] In addition, standardized verbal means for the communication of visually assessed color characteristics are limited.[1] Metamerism, light reflection, and individual characterization of natural teeth further contribute to variability in shade selection.

Previous authors have suggested other disadvantages with the use of shade guides.[2,3] First, the range of available colors in the shade guides is inadequate and the color samples are not logically distributed.[4] Second, there is a lack of consistency among and between dentists in using the shade guides to match colors.[2] Third, it is not possible to translate the results obtained from shade guides into the "Commission Internationale del'Enclairage" colour specifications.[5]

Moreover, due to difficult-to-control parameters during fabrication (layering), none of the commercially available dental shade guides are identical. None of the available dental shade guides are made of commercially available dental ceramics and as such have different light absorption and reflective properties. Despite all these, shade guides still are the only "standard" upon which determination of color is based in dentistry.[1] They provide a quick and cost-effective method for measuring tooth color. Success of the visual process depends on the level of skill and experience of the clinician, which is highly variable.[6]

An alternative to visual color assessment is the use of instrumental color measurement. Dental shade matching instruments, introduced in the late 1990s, aimed to reduce or overcome imperfections and inconsistencies of traditional shade matching. These encompass colorimeters, spectrophotometers, and imaging systems. These devices basically consist of a detector and signal conditioner and software that processes the signal to make the data usable in the clinic or laboratory.[7]

Instrumental color analysis offers a potential advantage over visual color determination because instrumental readings are objective, can be quantified, and are more rapidly obtained.[8] For visual shade selection, the light used in the environment is an important factor. However, as spectrophotometers operate with an internal light source, the measurement surface is illuminated with this standardized light during capture. Thus, the degree of accuracy depends on the instrument used,[9-11] type of material, opacity, texture, and translucency of the measured side.[5,12] To apply digital shade selection for human teeth, the accuracy and reproducibility, as well as inter examiner reliability, must be considered. However, spectrophotometers and colorimeters have been used primarily in research and not in clinical practice.[8] This has been attributed to the complexity and cost of the equipment and, more importantly, difficulty to use them in *in vivo* conditions.

The results of investigations of the relationship between visual and instrument shade matching have been inconclusive. Previous studies[13-15] have indicated inconsistencies of devices in measuring color parameters or matching teeth to shade systems. Hence, further studies are required to determine the reliability of these instruments before they may be incorporated into routine clinical use.

The purposes of this study were to compare the accuracies of visual matching and an intra-oral spectrophotometer among dentists, using two shade guide systems. The null hypothesis was that there would be no difference between methods and the shade guides used.

METHODS

Two sets each of the commercially available shade guide systems: The VITAPAN Classical™ and the VITAPAN 3D Master™ (Vita Zahnfabrik, Bad Sackingen, Germany) were used for conducting this study. One set was used for determining the target control tabs while the conventional visual shade matching was performed using second set of each shade guide system.

Ten examiners with normal color vision who were trained to use the equipment participated in the visual shade matching process. Six of them were specialists in prosthodontics and four were specialists from conservative dentistry. Visual acuity of the participants was tested using the standard Ishihara test for color blindness. The spectrophotometric shade matching was performed by two independent examiners using an intraoral spectrophotometer (VITA Easyshade™, Vita Zahnfabrik, Bad Sackingen, Germany). This was done to determine the interrater agreement of the equipment.

Five shade tabs from the VITAPAN 3D Master™ (one from each value group) and four shade tabs from the VITAPAN Classical™ were selected as the target control tabs from one set of each shade guide system. These were then obscured by tape and assigned numbers. Each of the nine target control tabs were repeated 3 times by each of the 10 examiners in the visual method of shade matching while each target control tab was repeated 5 times by the two examiners in the spectrophotometric method. Thus, a total of 360 readings were recorded (270 for visual method and 90 for spectrophotometric method).

Before doing the visual selection, an explanation was given to each volunteer on how to use the shade guides, irrespective of whether they had used them previously. The volunteers were then allowed to look at the control tabs and decide what they thought was the best shade match. The volunteers were allowed to pick up the shade tabs, and no time limits were imposed. Control tabs were given one by one in a random manner.

The examiners were independently required to match all the masked target control tabs of both shade guide systems using the respective shade guide system, i.e. masked shade tab of VITAPAN Classical™ with the VITAPAN Classical™ shade guide. The matching was done under standardized lighting conditions. 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.

The Easyshade device was used according to the manufacturer's instructions. It was calibrated after each participant's usage. For determining the accuracy of the spectrophotometer, two examiners were required to match the control tabs with each tab being matched 5 times. The spectrophotometer was used in the "shade tab" mode. The examiners were asked to match the shade tab at its middle third.

The study was carried out 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. Once data collection was complete, the identity of the control tabs were revealed and noted. Scores were assigned on a correct or incorrect basis and no allowances were made for "closeness" to the correct answer.

The statistical analysis was done using statistical software (SPSS 16 for Windows, Chicago, Illinois, USA; AgreeStat 2013.1, Montgomery Village, Maryland, USA and MedCalc software, Ostend, Belgium). The study focused to determine the accuracy of shade matching and precision (interrater agreement) of the two methods.

Differences in proportion between examiners and shade guide systems were analyzed using Chi-square tests. The difference in accuracy for the visual method was also compared among the two specialties of examiners (prosthodontics and conservative dentistry). Cohen's kappa was calculated to estimate interrater agreement with the spectrophotometric method as only two examiners were involved. For the visual method, Fleiss kappa scores were determined as more than two examiners were involved. $P < 0.05$ was considered significant for all tests.

RESULTS

A comparison of accuracies between shade matching methods revealed that the visual method was better than the spectrophotometric method [Table 1]. When the accuracies between the shade guides used in the study were compared, interesting results were obtained. In the spectrophotometric method, VITAPAN Classical™ shade guide was more accurate than the VITAPAN 3D Master™ shade guide. In the visual method of shade selection, the VITAPAN 3D Master™ shade guide proved to be better giving 73 correct responses out of the total 150 responses [Figure 1].

The comparison of inter examiner accuracy between the visual and spectrophotometric methods produced interesting results. The responses given by the machine were consistent irrespective of the examiners using it. In addition, they were exactly the same whether correct or incorrect [Tables 2 and 3].

The visual method of shade matching showed different results for inter examiner accuracy. The numbers of correct and incorrect responses for the shade tabs from both the shade guides were different for each of the examiners who participated in the study [Figures 2 and 3].

There was no significant difference in the accuracy between the two specialties while using the VITAPAN Classical™ shade guide. However, the examiners from prosthodontics showed a statistically significant higher accuracy when using VITAPAN 3D Master™ shade guide [Figure 4].

The level of interrater agreement was determined for both the methods and shade guides [Table 4]. The spectrophotometric method showed a good level of interrater agreement, irrespective of the shade guide used. The agreement was fair for the visual method while using the VITAPAN 3D Master™ shade guide and it was least for the visual method when the VITAPAN Classical™ shade guide was employed.

Table 1: Comparison of accuracy between shade matching methods

Method	Correct (%)	Incorrect (%)	Total *n* (%)	Test statistic χ^2	df	*P*
Spectrophotometer	10 (11.11)	80 (88.89)	90 (100)	26.114	1	0.000*
Visual	109 (40.37)	161 (59.62)	270 (100)			

*The difference in proportions was statistically significant (Chi-square test)

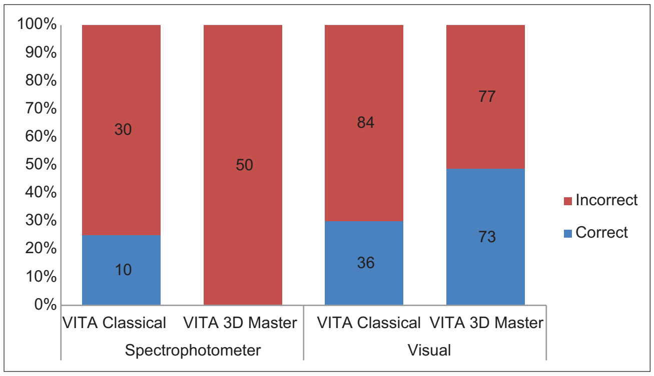

Figure 1: Comparison of accuracy between visual and spectrophotometric methods

	Correct	Incorrect
Spectrophotometer		
VITA Classical	10	30
VITA 3D Master	0	50
Visual		
VITA Classical	36	84
VITA 3D Master	73	77

Table 2: Comparison of accuracy between examiners by spectrophotometric method using VITAPAN Classical™ shade guide

Examiner	Correct (%)	Incorrect (%)	Total *n* (%)	χ^2	df	*P*
Examiner 1	5 (25)	15 (75)	20 (100)	0.000	1	1.000*
Examiner 2	5 (25)	15 (75)	20 (100)			
Total *n* (%)	10 (25)	30 (75)	40 (100)			

*There was no statistically significant difference in proportions (Chi-square test)

Table 3: Comparison of accuracy between examiners by spectrophotometric method using VITAPAN 3D Master™ shade guide

Examiner	Correct (%)	Incorrect (%)	Total *n* (%)
Examiner 1	0 (0)	25 (100)	25 (100)
Examiner 2	0 (0)	25 (100)	25 (100)
Total *n* (%)	0 (0)	50 (100)	50 (100)

Table 4: Comparison of inter rater agreement among different methods

Method	Shade guide	Statistic	Value	Strength of agreement
Spectrophotometer	VITAPAN Classical™	Cohen's kappa	0.774	Excellent
Spectrophotometer	VITAPAN 3D Master™	Cohen's kappa	0.781	Excellent
Visual	VITAPAN Classical™	Fleiss kappa	0.153	Poor
Visual	VITAPAN 3D Master™	Fleiss kappa	0.282	Poor

DISCUSSION

The present study compared the accuracies of visual and spectrophotometric (VITA Easyshade™) shade matching using two shade guide systems: VITAPAN Classical™ and

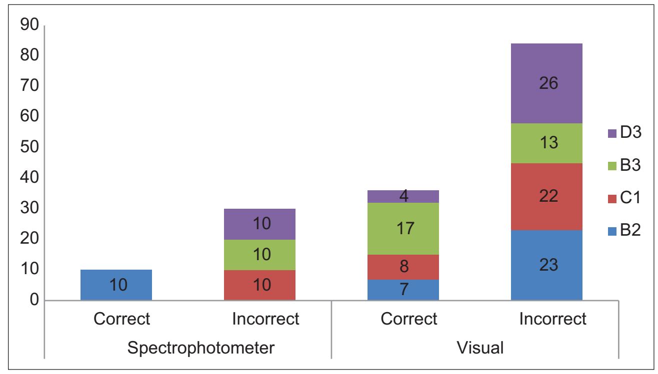

Figure 2: Accuracies of shade tabs from VITA Classical Shade Guide

Shade tab	Spectrophotometer		Visual	
	Correct	Incorrect	Correct	Incorrect
B2	10	0	7	23
C1	0	10	8	22
B3	0	10	17	13
D3	0	10	4	26

VITAPAN 3D Master™. The results support rejection of the null hypotheses that there is no difference in accuracies between the two methods of shade selection.

Accuracy and precision are two separate aspects of color measurement.[16] Accuracy indicates the ability of the method to provide a correct shade match. In other words, accuracy or conformity refers to the concept of examining how closely the observed measurement conforms to a "correct result," which is available as the "reference," "criterion," or "gold standard" value for each measurement. Precision comprises the repeatability of the measuring method over time or the reproducibility of the whole measuring process.

Hence, in this study, accuracy refers to the exact reproduction of the masked shade tab using either the spectrophotometric method or the visual method. The study showed that the conventional visual method of shade matching was more accurate (40.37%) than the spectrophotometric method (11.11%) irrespective of the shade guide used.

Previous studies have shown conflicting results. While most of the studies[1,17,18] indicate that shade matching instruments are more accurate, evidence to the contrary is also available.[8,19,20]

A recent study by Hugo *et al*.[19] demonstrated that human examiners showed a significantly higher agreement value when compared with computer-aided tooth shade determination device. The devices reached on average only a value of 28.6%. Ratzmann *et al*.[20] in 2011 showed that validity was better for visual than for electronic color assessment. Reproducibility of the electronic device by means of the Shade Inspector™ was given for the VITAPAN Classical™ and 3D Master™

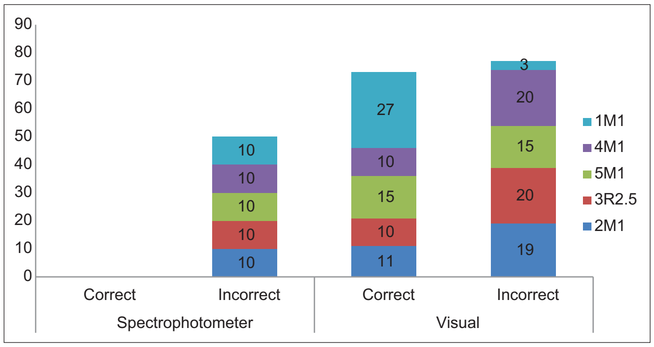

Figure 3: Accuracies of shade tabs from VITA 3D Master Shade Guide

Shade tab	Spectrophotometer		Visual	
	Correct	Incorrect	Correct	Incorrect
2M1		10	11	19
3R2.5	0	10	10	20
5M1	0	10	15	15
4M1	0	10	10	20
1M1	0	10	27	3

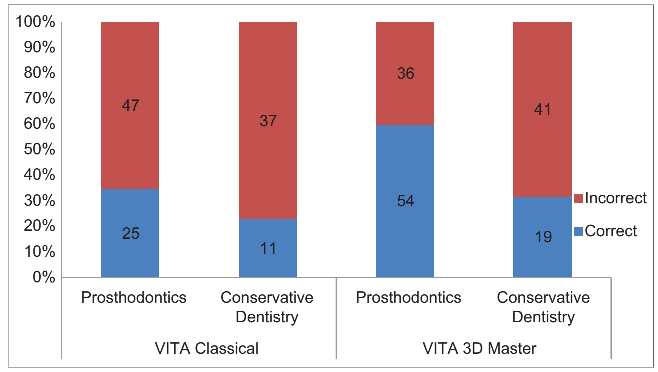

Figure 4: Comparison of accuracy of visual shade matching between specialties

	Correct	Incorrect
VITA Classical		
Prosthodontics	25	47
Conservative Dentistry	11	37
VITA 3D Master		
Prosthodontics	54	36
Conservative Dentistry	19	41

systems in that study. These results are very similar to those obtained in the present study, except that the accuracy for spectrophotometric method in the present study was as low as 11.11%.

The fact that this study used shade tabs as targets could have led to a reduction in accuracy as only an exact match was considered accurate. The relative closeness of the response given by the spectrophotometer to the target shade tab was not considered. This could partly account for the reduced accuracy of the spectrophotometer.

Determination of natural tooth color is partially difficult because there is no gold standard for human teeth.[21] Since natural teeth present with more shade variations than shade guides, one should expect even less result in the *in vivo* than in the *in vitro* experiment. The fact that the machine could not accurately match the standardized shade tab casts serious doubts over the utility of this spectrophotometer for routine clinical use.

A critical evaluation of the studies reporting better results with spectrophotometers revealed that most of them were concerned with repeatability. The second objective of this study was to assess the precision or level of interrater agreement for both shade matching methods. Agreement is assessed without a "gold standard" criterion. It is determined by how closely two observations agree, but not whether they are correct.

The study results showed that the spectrophotometric method produced a greater level of interrater agreement when compared to the conventional visual method. This is in accordance with the literature.[21] Thus, it can be inferred that the interexaminer agreement of the spectrophotometer is good even though doubts still remain regarding the accuracy of the shade match.

Another objective was to compare the effectiveness of the most commonly used shade guides: The VITAPAN Classical™ and the VITAPAN 3D Master™ with both shade matching methods.

The results indicate that while the spectrophotometric readings were more accurate for VITAPAN Classical™ (25%), not even one tab from VITAPAN 3D Master™ was correctly matched even once by the machine. In contrast, the accuracy with visual method was better for VITAPAN 3D Master™ (48.7%) than the VITAPAN Classical™ (30%).

These results are consistent with previous studies.[22-25] Oh *et al.*[24] in 2009 stated that visual shade matching gave better agreement with VITAPAN 3D Master™ than VITAPAN Classical™ when multiple observers were employed.

It may be possible that there were too many shades to choose from, i.e. the 26 shades of the VITAPAN 3D Master™ compared to the VITAPAN Classical™ which only has 16 shades. But, the VITAPAN 3D Master™ is designed to cut choices down to seven in one step if used properly so it should not be a problem. However, all depends on whether the VITAPAN 3D Master™ system is used properly.

The comparison of shade matching accuracy between faculty from prosthodontics and conservative dentistry revealed instigating results. The significantly higher accuracy and inter rater agreement levels of prosthodontists with the VITA 3D Master™ needs further discernments. Hammad[22] has earlier reported better shade matching ability for prosthodontists.

The difference obtained in this study could be attributed to the fact that the VITA 3D Master™ shade guide is routinely used by prosthodontists. This also indicates that this shade guide has a substantial learning curve before it can be used with considerable accuracy.[26]

All experiments have inherent limitations and the present study offers no exception. Theoretically, instrumental readings are objective, can be quantified, and more rapidly obtained.[8] However, the VITA Easyshade™ digital spectrophotometer did not perform as well as expected. The machine was calibrated between measurements and switched off after testing 10 tabs so as to avoid overheating it. The consistency of the results indicated a calibration issue may have been the problem, but the machine got the shade B2 from VITAPAN Classical™ correct all the time by both the examiners, which indicated an error intrinsic to the operation or function of the machine. This could be a possibility as only one instrument was employed for the study.

Another shortcoming of the study is that when spectrophotometer was used, the probe tip was arbitrarily positioned on the middle third. A positioning device to replicate the same area was not used. However, the study results reveal that this has not affected the repeatability issues of the spectrophotometer.

The VITA Easyshade™ machine did not yield many correct results, but its reproducibility was impressive. Further development of the VITA Easyshade™ machine may permit fast and accurate shade matching in the future.

CONCLUSION

Within the limitations of this study, the following conclusions were obtained:

- A comparison of accuracies between shade matching methods revealed that there were significant differences with the visual method producing more accurate results than the spectrophotometric method
- The spectrophotometer showed far better interrater agreement scores irrespective of the shade guide used
- In the spectrophotometric method, VITAPAN Classical™ shade guide was more accurate (25%) than the VITAPAN 3D Master™ shade guide
- In the visual method of shade selection, the VITAPAN 3D Master™ shade guide proved to be better than the VITAPAN Classical™ shade guide
- A comparison of interrater agreement between participants from the two specialties (prosthodontics and conservative dentistry) showed that the raters from prosthodontics had better scores for both the shade guides used.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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