Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/18934
DOI URL: http://dx.doi.org/10.21474/IJAR01/18934

RESEARCH ARTICLE

EVALUATION OF EFFICACY OF COLOUR CORRECTED LIGHT SOURCE IN DETERMINING THE ACCURACY OF SHADE MATCHING DONE WITH A COMMONLY USED SHADE GUIDE SYSTEM BY CONVENTIONAL VISUAL METHOD AND AN INTRA ORAL SPECTROPHOTOMETER

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Manuscript Info

Manuscript History
Received: 18 April 2024
Final Accepted: 23 May 2024
Published: June 2024

Key words:-
Dental Shade Matching, Colour Corrected Light Source, Spectrophotometer, Visual, Accuracy, Repeatability, Shade Guide

Abstract

Aim: The objective of this study was to evaluate the efficiency of colour corrected light source in shade matching and to determine accuracies and inter-rater agreement of three shade matching methods (conventional visual method, visual method using colour corrected light source and spectrophotometric method).

Methodology: In the conventional visual method and the visual method using colour corrected light source, four examiners with normal colour vision matched five target control shade tabs taken from the VITAPAN 3D Master™ shade guide, with other full set of the same shade guide. Shade matching with the colour corrected light source was done under "daylight" mode simulating 5500K or natural daylight. Each tab was matched three times to determine repeatability of visual examiners. In the spectrophotometric method, two independent examiners matched the control tabs with three repetitions for each tab. The data was collected and statistical analysis was performed.

Results: Visual method using colour corrected light source produced more accurate results (80%) than the conventional visual method (68.3%) and spectrophotometric method (0%), thus proving the efficacy of colour corrected light source ($p<0.05$). All three methods exhibited poor inter-rater agreement.

Conclusion: The question is whether handheld light correcting devices and digital assessments are clinically useful or are they unreliable andunnecessary costly. Even though visual shade matching is subjective, it is not inferior and should not be underrated. The low accuracy value obtained for the spectrophotometer may be a misrepresentation of the machine's capabilities due to its inability to measure any reading as"close" to the correct value. If both analyses are combined, digital determination of the basic shade and visual determination of the effects, can provide the best possible esthetic outcome. Although human eye will be the finalarbitrator, success can best be achieved by combining traditional artistic techniques with advancements in technology, complemented with innovations in colour-related research, education, and training of dental professionals.

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Introduction

Shade determination is one of the key factors in creating an esthetically successful restoration.Shade selection is more of an art than a science. Success in color construction and communication can best be achieved by combining traditional artistic techniques with the advancements in technology. The advances in technology must be complemented with innovations in color-related research, education, and training of dental professionals.

The most important factor in shade-matching is the lighting condition.[1] The correct light source allows the clinician to get the shade right the first time and avoid remakes, extra appointments and increase in cost. Since natural light conditions vary, recommendations for shade-matching include proper colour temperature that come up to 5500k and a colour-rendering index (CRI)greater than 93 for dental professionals. The CRI measures the equal balance of all the visible wavelengths,and viewing teeth under diffuse illumination will minimise the distortion of the reflected light. A low light intensity will make the clinician miss the fine details and complicate hue perception.

The value guide should be used first, preferably with low light levels, even if the operator must squint, since it is the best for value evaluation.[2] There is strong and reliable evidence that supports the use of a light-correcting source during tooth shade-matching. Shade-matching was also much better under a light-correcting source when compared to natural or clinical light.[3] Even when light conditions are improved by using a low temperature illuminator, there is a notable improvement in colour vision-deficient individuals.[4,5]In another Irish study,[6] the overall results indicated that the most beneficial factor for shade-taking was the light-correcting source. The closer the spectral reflectance curves (optical properties) of the two materials to be matched, the more successful the colour matches will be, thereby minimising metamerism.[7–9]

Colour corrected light source (Rite-lite2)

Rite-lite2(Figure 1) is a portable and wireless light-correcting device which has been designed to aid in shade-matching.Clad in satin-finished aluminium and weighing 184.3g, the round top has an external diameter of 5.3cm and 12 LEDs. The inner window-hole for viewing patient's teeth has a diameter of 3cm. The patient side of the round top section illuminates the dentition from all directions to avoid glare or distortions by direct reflections. The bottom section is a cylindrical handle that is 9.6cm long with a diameter of 2cm.

Fig. 1: Colour corrected light source (Rite-lite2).

The objectives of the study were:

1. To compare the accuracy of shade matching by conventional visual method undernatural daylight and by using a colour corrected light source operated under"daylight" mode.

2. To compare the accuracy of shade matching by conventional visual method using colour corrected light source and an intra-oral spectrophotometer.
3. To compare the precision (inter-rater agreement) of the visual method, with andwithout using colour corrected light source, and the spectrophotometric shade matching methods.

Method

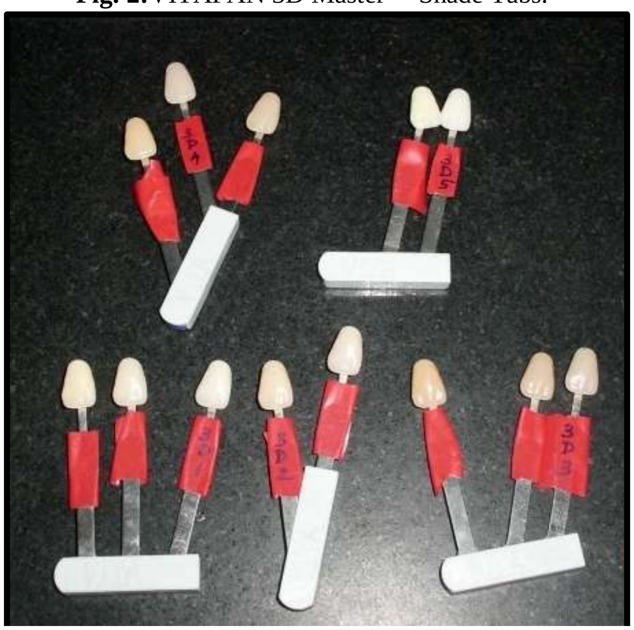
Two sets of a commercially available shade guide systemVITAPAN 3D Master^{TM} and a colour corrected light source (Rite-lite2)were used for conducting this study. An intraoral spectrophotometer (VITA Easyshade^{TM}) was used to record the spectrophotometric readings.

Four examiners with normal color vision who were trained to use the equipment and the shade guide system and colour corrected light source participated in the visual shade matching process. All examiners were post graduates in Prosthodontics. 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 to determine the inter-rater agreement of the equipment.

Five shade tabs from the VITAPAN 3D Master^{TM} were selected as the target control tabs from one set of the shade guide system. These were then obscured by tape and assigned numbers. (Figure 2). Natural extracted teeth were not used in this study as they dehydrate over time and result in shade variables which are undesirable, hence the use of shade guide tabs for standardization.[10]

Fig. 2:VITAPAN 3D Master^{TM} Shade Tabs.



Each of the five target control tabs were repeated three times by each of the four examiners in the visual method of shade matching, first in the conventional manner and then by using a colour corrected light source. Each target control tab was repeated five times by the two independent examiners in the spectrophotometric method. A total of 150 readings were recorded. (60 readings for visual, 60 readings for visual method using colour corrected light source and 30 readings for spectrophotometric method)

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. The tabs were revealed only after all the observations were recorded.

An explanation was then 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. Volunteers were given the control tabs one by one in a random manner. Participants were not required to do the test in any particular order, and were given no help in choosing a shade. Participants were however told that there were no doubles.

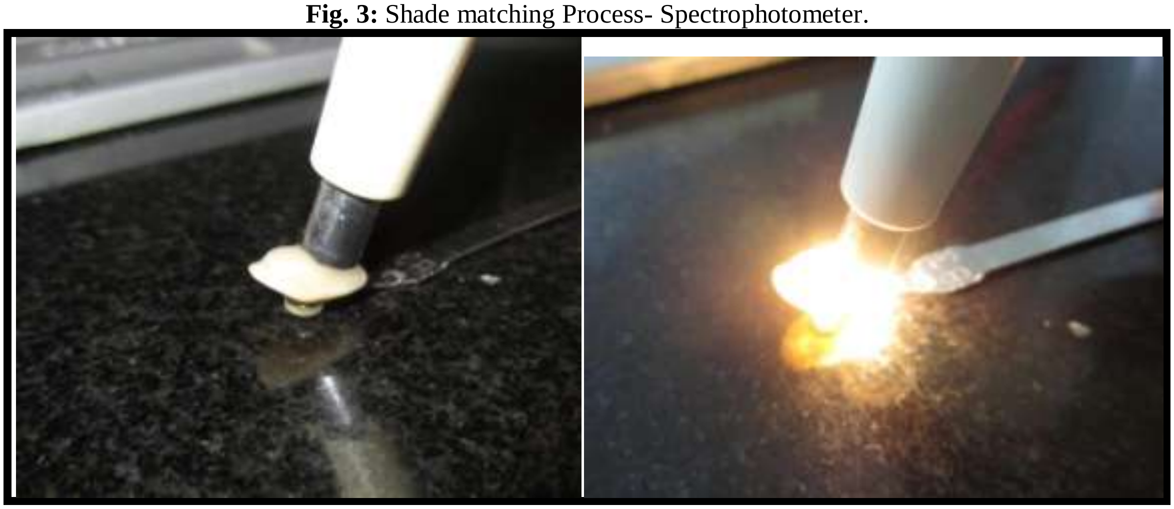
Visual Method –
The examiners were independently required to match all the masked target control tabs of VITAPAN 3DMASTER™ with another complete set of the VITAPAN 3DMASTER™ shade guide.

Visual method with colour corrected light source –
The examiners were independently required to match all the masked target control tabs of VITAPAN 3DMASTER™ with another complete set of the VITAPAN 3DMASTER™ shade guide by viewing through the inner window hole of the colour corrected light source (Rite-lite2) in the "daylight" mode. The distance at which to hold the color corrected light source was not specified.

The matching was done under standardized lighting conditions. An A4 sheet of grey card was used to rest the subject's eyes betweenshade assessments. The ideal background color is neutral gray as it has no complimentary color and is restful to the cones.[10] Pink background is also considered an ideal colour reference.[1] Examiners were asked to look at it for 15 seconds to avoid colour fatigue.

Spectrophotometric method-
Two independent examiners were required to match the control tabs with each tab being matched five times. The spectrophotometer was used in the "shade tab" mode. The examiners were asked to match the shade tab at its middle third as previous studies have shown that the basic shade is best represented at the middle third.[44] (Figure 3) The inter examiner reproducibility and the intra examiner repeatability of the spectrophotometer was thus assessed.

Fig. 3: Shade matching Process- Spectrophotometer.



Once data collection was complete the identity of the control tabs was revealed and noted. Scores were assigned strictly on a correct or incorrect basis.

The statistical analysis was done using statistical software (SPSS 25 for Windows, Agreestat2013.1, MedCalc software). The difference in accuracy for the conventional visual method,visual method using colour corrected light source and the spectrophotometer was analyzed using Chi square tests.

Cohen's kappa was calculated to estimate interrater agreement with the spectrophotometric method as only two examiners were involved. For the visual method, however, Fleiss kappa scores were determined based on the criteria proposed by Fleiss.[11] P values < 0.005 were considered significant for all tests.

Results

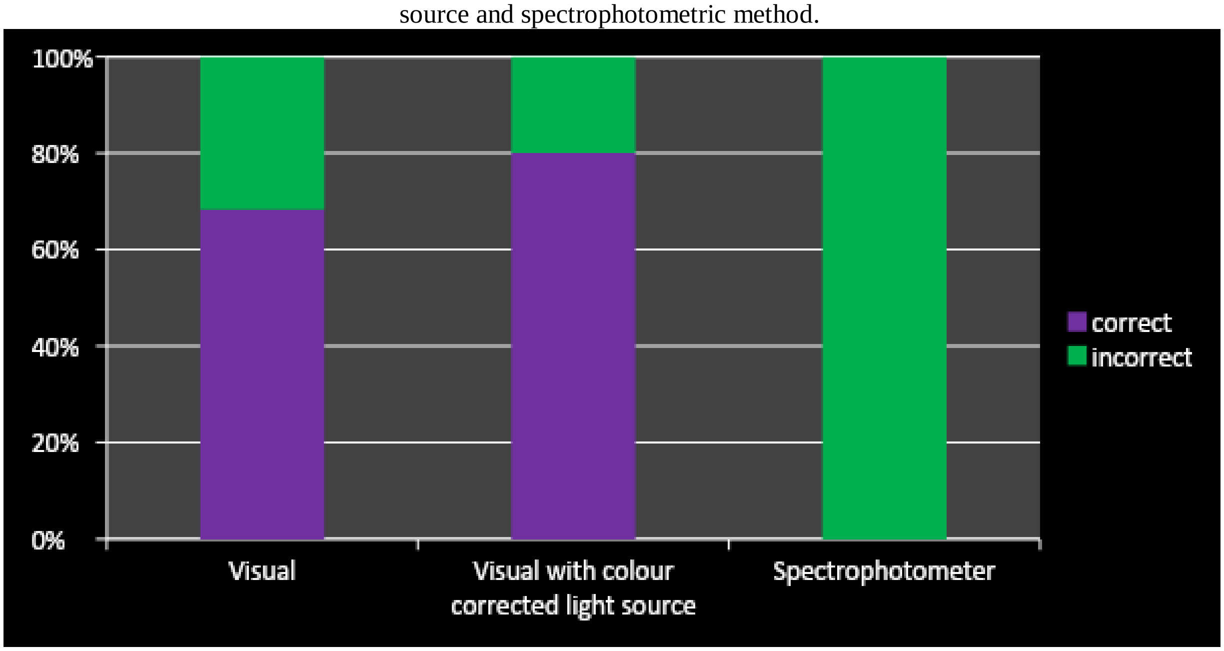
A comparison of accuracies between shade matching methods revealed that the visual method using colour corrected light source was better than the conventional visual method and spectrophotometric method. The difference in accuracy between the three methods was statistically significant. (Table 1, Figure 4)

Table 1:COMPARISON OF ACCURACY BETWEEN SHADE MATCHING METHODS.

Method	Correct (%)	Incorrect (%)	Total	Chi square	df	p value
Visual	41	19	60	56.40	2	00.000*
Visual with colour corrected-light source	48	12	60			
Spectrophotometer	0	30	30			

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

Fig.4: Comparison of accuracy between conventional visual method,visual method using colour corrected light source and spectrophotometric method.



Unfortunately, the spectrophotometer gave all the responses incorrect when the shade tabs from the VITAPAN 3D Master™ shade guide were matched. The accuracy between shade guides evaluated by visual method using colour corrected light source and the conventional visual method showed varied results with the shade guide. (Figure 5, Figure 6)

The comparison of inter examiner accuracy among the three methods produced interesting results. The responses given by the machine were consistent irrespective of the examiners using it. They were the same whether correct or incorrect. No correct responses were given by the machine for both the examiners. (Table 4)

The conventional visual method of shade matching showed different results for inter-examiner accuracy. The number of correct and incorrect responses for the shade tabs from the shade guide were different for each of the examiners who participated in the study. (Table 2, Table 3)

The level of inter-rater agreement wassummarized using the classification proposed by Fleiss.[11] All the three methods showed poor level of inter-rater agreement. (Table 5)

Fig.5: Comparison of Accuracy between Shade Tabs from VITAPAN 3D Master™ Shade Guide by Visual Method.

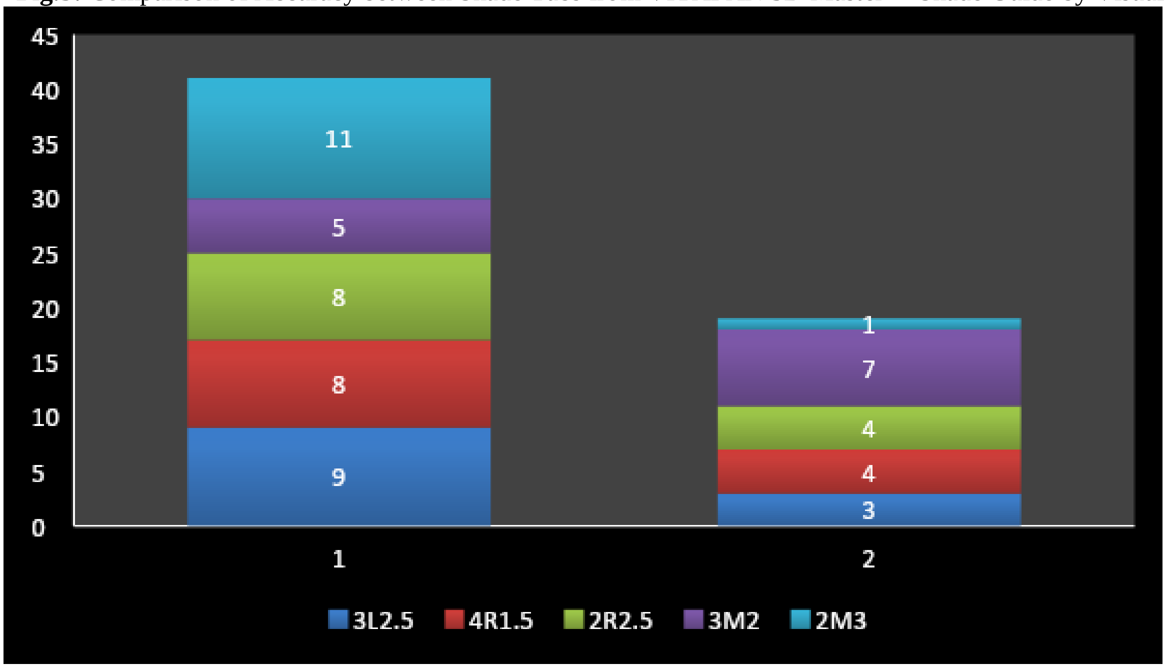


Fig.6:- Comparison Of Accuracy Between Shade Tabs from VITAPAN 3D- Master™ Shade Guide by Visual Method Using Colour Corrected Light Source.

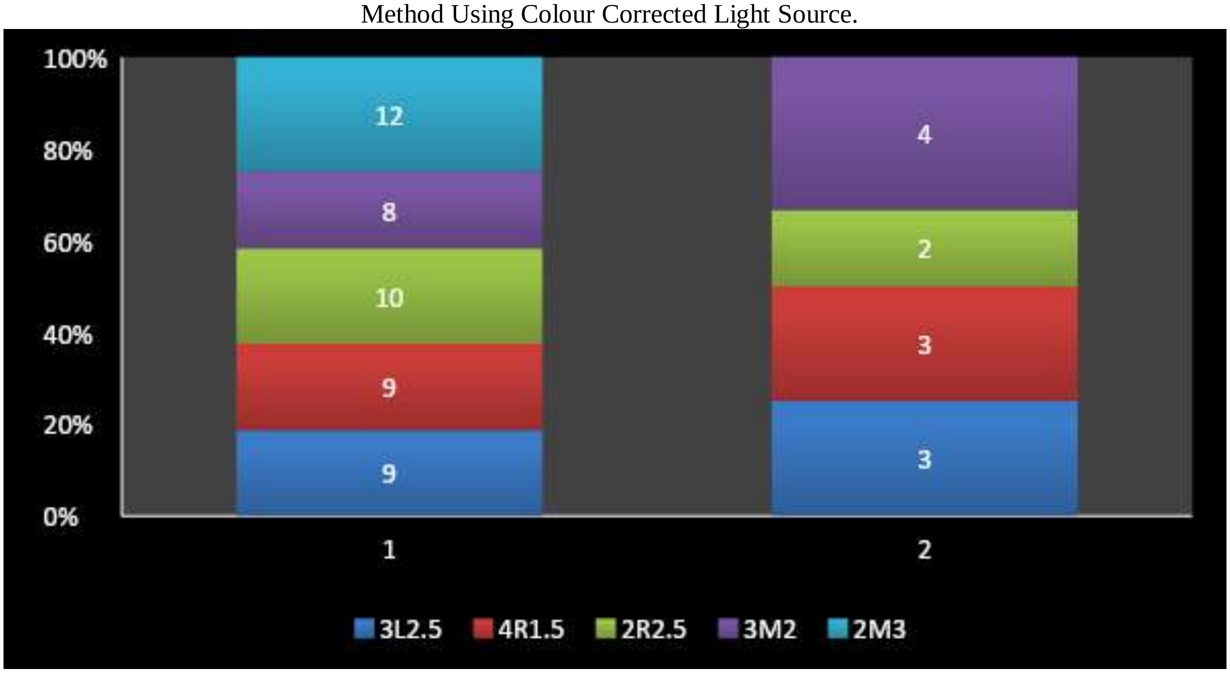


Table 2: COMPARISON OF ACCURACY BETWEEN EXAMINERS BYVISUAL METHOD USING VITAPAN 3D-MASTER™ SHADE GUIDE.

Examiner	Correct (%)	Incorrect (%)	Total	Chi square	df	p value
Examiner1	9(22)	6(31.6)	15			
Examiner2	10(24.4)	5(26.3)	15			
Examiner3	10(24.4)	5(26.3)	15	1.463	3	0.691*

Examiner4	12(29.3)	3(15.8)	15			
Total	41(100)	19(100)	60			

* The difference in proportions was statistically insignificant

Table 3:COMPARISON OF ACCURACY BETWEEN EXAMINERS BY VISUAL METHOD WITH COLOURCORRECTED LIGHT SOURCE USING VITAPAN 3D-MASTER^{TM} SHADE GUIDE.

Examiner	Correct (%)	Incorrect (%)	Total	Chi square	df	p value
Examiner1	11(22.9)	4(33.3)	15	2.500	3	0.475*
Examiner2	11(22.9)	4(33.3)	15			
Examiner3	12(25)	3(25)	15			
Examiner4	14(29.2)	1(8.3)	15			
Total	48(100)	12(100)	60			

* The difference in proportions was statistically insignificant

Table 4:COMPARISON OF ACCURACY BETWEEN EXAMINERS BY SPECTROPHOTOMETRIC METHOD USINGVITAPAN 3D-MASTER ^{TM} SHADE GUIDE.

Examiner	Correct (%)	Incorrect (%)	Total
Examiner 5	0	15(100)	15(100)
Examiner 6	0	15(100)	15(100)
Total	0	15(100)	15(100)

Table 5:COMPARISON OF INTER-RATER AGREEMENT AMONG DIFFERENT METHODS.

Method	Shade Guide	Statistic	Value	Strength of Agreement
Visual	Vitapan 3D-Master^{TM}	Fleiss Kappa	-0.111	Poor
Visual with colour corrected light source	Vitapan 3D-Master^{TM}	Fleiss Kappa	-0113	Poor
Spectrophotometer	Vitapan 3D-Master^{TM}	Fleiss Kappa	-0.161	Poor

*as proposed by Fleiss[11]

Discussion:

The present study evaluated the efficacy of a colour corrected light source in determining the shade and compared the accuracies of conventional visual method, visual method using colour corrected light source and intraoral spectrophotometric (VITA Easyshade^{TM}) method using VITAPAN 3D Master^{TM}shade guide system. The results support rejection of the null hypothesis that the colour corrected light source is not efficient in determining the accuracy of shade matching.

In this study, accuracy refers to the exact reproduction of the masked shade tab using either the spectrophotometric method or the visual method with and without using colour corrected light source. The study showed the visual method using colour corrected light source to be more accurate than the conventional visual method and spectrophotometric method.

One possible explanation for this is that the examiners were focused solely and directly on the shade matching area observed through a small window of the handheld light. This could have reduced background distraction and increased focus on the shade-matching exercise. These are clinically favourable results (additionally,having a viewing booth in a clinical setting is not practical). The advantages of the evaluated handheld lights compared with other available shade-matching aids include their portability, user friendliness, and affordability.[12]

The correct light source allows the clinician to get the shade right the first time and avoid remakes, extra appointments and increase in cost.[1] In the United Kingdom, clinician scientists combined the use of colour-correcting and digital recording devices showing an improved ability to match dental shades when compared to the digital device alone under normal light conditions.Shade-matching was also much better under a light-correcting source when compared to natural or clinical light.[3] Even when light conditions are improved by using a low temperature illuminator, there is a notable improvement in colour vision-deficient individuals.[4,5]

On comparison of the conventional visual method and spectrophotometric method, the spectrophotometer was found to be less accurate. Previous studies have shown conflicting results. While most of the studies[13],[14–16] indicate that shade matching instruments are more accurate, evidence to the contrary is also available.[17–19]

In a study by Hugo B et al[20], the authors concluded that computer-aided color shade determination of natural teeth seems to not reflect human perception. Another study conducted in 2011 by Ratzmann A et al[21] also showed that validity was better for visual than for electronic color assessment. Another recent study by Sarafianou A et al[16] in 2012 suggested a particularly low level of agreement for Easyshade and SpectroShade readings performed under any of the illuminants tested suggesting poor inter device reliability.

These results are similar to those obtained in the present study. It is pertinent to evaluate the reasons for such low accuracy levels for the spectrophotometric method in the study.

The influence of methodology on the accuracy levels of spectrophotometric method also needs to be considered. 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. This could partly account for the reduced accuracy of the spectrophotometer. Majority of the readings obtained were in the same value-range as that of the target shade tabs, but were considered incorrect as only the exact match was deemed correct.

The third objective of this study was to assess the precision or level of inter-rater agreement for the three shade matching methods. It is determined by how closely two observations agree, but not whether they are correct. The study results showed that the conventional visual method, visual method using colour corrected light source and spectrophotometric method produced poor level of inter-rater agreement.

The results obtained in this study are not in accordance with the literature in that the spectrophotometer provides far better inter-rater agreement as compared to the conventional visual method. In the systematic review conducted by Chen H et al[22] in 2012, the authors have reviewed eighteen studies that have reported Inter-evaluator/Inter equipment agreement.

The exceptions were one study[23] in which spectrophotometers failed to consistently produce greater agreement than conventional visual measurement, two studies[24,25] in which the precision percentage of a spectrophotometric measurement was smaller than that of a colorimeter, and another study[26] in which the spectrophotometric shade match was the least reproducible. The relatively lower reproducibility yielded by spectrophotometers in these studies may have been caused by device-dependent biases [27,28].

Thus, it can be inferred that the poor level of inter- rater agreement of the spectrophotometer is in this study was due to the device dependent biases and the strict and narrow criteria for choosing the correct response as even the responses which were very close to or within the same value range as the target tabs were considered incorrect.

Another perspective to reflect upon is the validity of evaluating inter rater agreement as the response given by the machine is objective and does not depend on the examiner using it, except for the correct placement of the spectrophotometer on the shade tab.

The poor level of inter-rater agreement of the visual methods, with and without using colour corrected light source can be attributed to the difference in subjective perception of the examiners, education and training, gender, color deficiency, and numerous physiological and psychological factors (fatigue, age, nutrition, medications).[12]

Strengths and limitations

The study reveals marked differences in accuracies between the visual methods, with and without using colour corrected light source and instrumental methods of shade matching. As the shade tabs used in the study had definite predetermined values, the results of matching these control tabs could be certainly assigned as correct and incorrect. Hence, the study design can be considered as the best predictor for accuracy of shade matching. Moreover, the responses with relative closeness to the correct shade tab was deemed incorrect which led to the reduced accuracy level of the spectrophotometer.

To test the accuracy of any electronic device intended for use in the oral environment, an intraoral standard must be developed. Despite this lack in standardization, the shade guides are the "de-facto standard'' for color determination in dentistry,[29] hence the advantage of using shade tabs as target controls.

A strength of this study is that the shade guide and the spectrophotometer used in the study are produced by the same manufacturer. This implies that the spectrophotometer VITA Easyshade™ has the software programmed in it to detect the shades from the VITAPAN 3D Master™ shade guide.

An added benefit is that it takes into consideration both repeatability and accuracy aspects of both methods of shade matching. In other words, precision and accuracy both of which are factors on a par to be considered are interpreted.

Theoretically, instrumental readings are objective, can be quantified, and more rapidly obtained[18]. 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. As discussed earlier, the reasons for such low levels of accuracy obtained for the spectrophotometer might have been because the responses were graded correct or incorrect with no measure of "closeness" to the correct value.

Another shortcoming 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.[28] However, the study results reveal that this has not affected the repeatability issues of the spectrophotometer. The hope for the spectrophotometer remains as it gave consistent results.

Another limitation was that this study was done taking readings from four examiners for visual shade matching and two independent examiners for spectrophotometer. The participation of four examiners cannot indeed expose nearly all the limitations of visual method of shade matching.

A shortcoming with the colour corrected light source is that the distance at which it was held from the target control tabs was arbitrarily decided. And the fact that the target control tabs had to be viewed through the glass made the shade matching process cumbersome and tiring for the examiners.

Comparison between visual and instrumental findings is a very attractive topic as it reveals the pros and cons of both methods. The answer whether to use visual or instrumental method for color matching in dentistry is: whenever possible, use both, as they complement each other and can lead towards a predictable appealing outcome[14,20,30].

Further research might evaluate the influence of different lights and polarizing filters on the shade selection of natural teeth because the optical properties of enamel and dentin are different from those of the shade tabs.[12] The superiority of a correcting light is a fact and could also be seen as convenient since it is portable, wireless and readily available as it is often found in the dental market industry.[1]

Conclusion

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

1. A comparison of accuracies between shade matching methods revealed that there were significant differences,proving that the colour corrected light source is more efficient in determining the accuracy of shade matching.
2. Comparison of conventional visual method and spectrophotometric methods show greater accuracy for the visual method.
3. Comparison of inter-rater agreement between examiners were poor for all the three methods.

4. Similar research evaluating the importance of lighting conditions and comparing the visual and instrumental shade matching methods is warranted in the future to delineate the exact roles for either technique to achieve the ultimategoal of providing an esthetic clinical outcome.

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