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Evaluation of the Accuracy and Repeatability of Tooth Shade Selection using an Intraoral Digital Scanner- An in vitro study

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Abstract

Rationale: To overcome the discrepancies of shade selection experienced due to commercially available shade guides, instruments such as spectrophotometer, colorimeter and digital cameras were introduced in dentistry which enabled clinicians to perform an objective analysis and compare the shades.

Aim: The purpose of this clinical study was to evaluate the color determination accuracy and repeatability of the TRIOS 3 Intraoral Scanner by comparing it with the Vita EasyshadeAdvamce 4.0 Spectrophotometer; to estimate the percentage of situations where there is determined shade difference with both devices.

Method: Fifty extracted teeth specimens (T1-T50) were tested for color analysis by using the VITA Easyshade Advance 4.0 and the Intraoral Scanner to obtain Vita Classic and 3D Master Shade values on the middle third of their labial surfaces.

Each of the 50 teeth were scanned 5 times with both devices to determine the accuracy and repeatability of the Intraoral Scanner in the determination of tooth shade. A total of 500 readings were obtained using both devices.

Results: The Yates Chi-square value for the accuracy of the Vita Classic and 3D Master shade of extracted teeth obtained using the Dental spectrophotometer and the Intraoral Scanner, gave values of 105.771 and 73.827 respectively.

Descriptive analysis value for the repeatability of the Vita Classic and 3D Master shade tab of the Intraoral Scanner was found to be 91.6% and 94.8% respectively.

Keywords: Shade Selection, Spectrophotometer, Intraoral Scanner, Vita Classic shade guide, 3D Master shade guide

Introduction

Dental restorations should restore both function and esthetics. An esthetic restoration is aimed at achieving biological, morphologic and optical acceptance replicating the natural teeth.[1]

Patient satisfaction for an esthetic restoration is associated primarily with the outline form, translucency and the shade of the artificial teeth.[2] Reproducing a tooth color requires a precise shade determination, which forms an important basis for achieving superior esthetics.[1]

To identify the color of a tooth and to reproduce it in a dental restoration, commercial shade guides have been used.[3]Difficulties of achieving an accurate shade match can originate from the subjective nature of the human color observation. Unlike science, art form is subordinate to the individual abilities of the dentist that influence the predictability and reproducibility of the finished restoration.[4]

When the tooth color is determined with shade guides, several shade tabs could be visually acceptable, because DE between the tabs and the tooth could be less than 3.7. It is also possible that all shade tabs are visually unacceptable because DE between the tabs and the tooth could be greater than 3.7.[6]

The visual color determination is influenced by multiple factors. This has led to the development of instrument shade-matching, based on self-lighting electronic devices. Instrument shade-matching allows a natural tooth color determination, regardless of the human and environment factors, as well as an accurate communication between dentists and technicians.To overcome the discrepancies of shade selection experienced due to commercially available shade guides, instruments such as spectrophotometer, colorimeter and digital cameras were introduced in dentistry which enabled clinicians to perform an objective analysis and compare the shades.Digital cameras, spectrophotometers, and colorimeters have been used to assist in color determination and have been reported to be more reliable than the visual method.[7]

Spectrophotometers are among the most accurate devices for determining tooth color. Their operation is based on the transmission of white light being dispersed through a triangular prism from 1 to 25 nm wavelength intervals, reflected from the surface of the tooth, and returned to the device, where the total quantity of energy of the color spectrum is registered. A dental spectrophotometer has been developed in order to eliminate the uncontrolled variables during the shade matching process. An attempt to eliminate the subjectivity of visual color analysis has led to the introduction of the digital shade analysis systems that attempt to eliminate the subjectivity of visual color analysis, reducing the chances of miscommunication of color. Hence, providing precise and uniform fabrication of aesthetic restorations by the dental laboratory technicians.[2,8,9]

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Intraoral Digital Scanners (TRIOS 3; 3Shape, CEREC AC OmniCam; Dentsply Sirona, CS 3500; Carestream Dental, and others) have been increasingly used to make digital scans of dental arches. TRIOS 3 is an Intraoral Digital Scanner with a shade-taking function. However, whether an Intraoral Digital Scanner with an integrated shade-taking function can substitute for colorimeters or spectrophotometers is unclear. Therefore, the purpose of this clinical study was to evaluate the color determination accuracy and repeatability of the TRIOS 3 Intraoral Digital Scanner by comparing it with the Vita Easyshade Advance 4.0 Spectrophotometer; to estimate the percentage of situations where there is determined shade difference with both devices.

AIM AND OBJECTIVES

An in vitro study to evaluate the accuracy and repeatability of tooth shade selection on extracted teeth using the Intraoral Digital Scanner.

MATERIALS AND METHOD

Fifty extracted teeth were used for this clinical research. The teeth were cleansed of visible blood and gross debris and stored in a secure container with a storage solution of 10% formalin. The teeth were then transferred to a solution of artificial saliva for 24 hours and maintained in a hydrated state. Each extracted tooth was embedded on a wax block. (Fig. 1)

The teeth specimens (T1-T50) were tested for color analysis using the VITA Easyshade Advance 4.0 (Control Group)(Fig. 3) and TRIOS3 (Test Group) to obtain Vita Classic and 3D Master Shade values on the middle third of their labial surfaces. These teeth specimens were dipped in artificial saliva, before each measurement.

Each specimen was placed on the 18% reflectance gray card (Fig. 2). The scan tip was moved at an angle of 90 degrees from the occlusal/incisal surface to the buccal/labial surface of the tooth. After scanning with the TRIOS3, the standard shape (circle) for shade determination was placed in the middle third of the tooth. (Fig. 4)

Each of the 50 teeth were scanned 5 times with both devices to determine repeatability of the Intraoral Scanner in the determination of tooth shade. A total of 500 readings were obtained using both devices. Each device gave 250 readings to determine the repeatability parameter and to determine the average base shade (most repeated) for each extracted tooth in the Vita Classic and Vita 3D Master Shade tabs.

The matches between the shades determined by the Vita Easy Shade and the Intraoral Scanner were used to estimate the accuracy of the Intraoral digital scanner in determining the shade.

The repeatability of the Dental Spectrophotometer and the Intraoral Scanner was evaluated by calculating the average percentage of the shades most often registered from the 5 measurements of the same tooth (n=50) according to the Vita Classic and 3D Master shade guides.

The data and results obtained from the study were then tabulated, represented graphically and statistically analyzed.

STATISTICAL ANALYSIS

Accuracy of the Vita Classic shade of extracted teeth obtained from the Intraoral Scanner compared to the Vita Easyshade Spectrophotometer using the Chi-square test

			Mean Vita Classic Shade (Intraoral Scanner)						***Total***
			A1	***A2***	***A3***	***B1***	***B2***	***B3***	
Mean Vita Classic Shade (Vita EasyshadeSpectrophotometer)	***A1***	***Count***	19	0	0	3	0	0	22
		% within group	86.4%	0.0%	0.0%	13.6%	0.0%	0.0%	100.0%
	A2	***Count***	0	3	0	0	1	0	4
		% within group	0.0%	75.0%	0.0%	0.0%	25.0%	0.0%	100.0%
	A3	***Count***	1	0	3	0	1	0	5
		% within group	20.0%	0.0%	60.0%	0.0%	20.0%	0.0%	100.0%
	A3.5	***Count***	0	0	0	0	2	0	2
		% within group	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%
	B1	***Count***	0	0	0	9	0	0	9
		% within group	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%
	B2	***Count***	1	0	0	1	3	0	5

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		% within group	20.0%	0.0%	0.0%	20.0%	60.0%	0.0%	100.0%
	B3	*Count*	0	0	0	0	1	2	3
		% within group	0.0%	0.0%	0.0%	0.0%	33.3%	66.7%	100.0%
Total		*Count*	21	3	3	13	8	2	50
		% within group	42.0%	6.0%	6.0%	26.0%	16.0%	4.0%	100.0%
Yates Chi square value: 105.771			**P value: <0.001****						

Accuracy percentage of the match/mismatch for the Vita Classic shade of extracted teeth obtained from the Intraoral Scanner

Match/Mismatch	***N***	***%***
Ideal match	39	78 %
Mismatch	11	22 %
Total	50	100 %

Accuracy of 3D Master shades of extracted teeth obtained from the Intra-oral scanner compared to the Vita Easyshade Spectrophotometer using the Chi-square test

			Mean 3D Master Shade (Intra oral scanner)						***Total***
			0M1	***0M3***	***1M1***	***1M2***	***2M2***	***2M3***	
Mean 3D Master Shade (Dental Spectrophotometer)	***0M3***	***Count***	1	12	0	0	0	0	13
		% within group	7.7%	92.3%	0.0%	0.0%	0.0%	0.0%	100.0%
	1M1	***Count***	1	0	2	1	0	0	4
		% within group	25.0%	0.0%	50.0%	25.0%	0.0%	0.0%	100.0%
	1M2	***Count***	0	1	0	19	1	0	21
		% within group	0.0%	4.8%	0.0%	90.5%	4.8%	0.0%	100.0%
	2L1.5	***Count***	0	0	1	0	0	0	1
		% within group	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%
	2M2	***Count***	0	0	0	2	2	0	4
		% within group	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%	100.0%
	2M3	***Count***	1	1	0	1	0	2	5
		% within group	20.0%	20.0%	0.0%	20.0%	0.0%	40.0%	100.0%
	3M3	***Count***	0	0	0	1	0	1	2
		% within group	0.0%	0.0%	0.0%	50.0%	0.0%	50.0%	100.0%
Total		***Count***	3	14	3	24	3	3	50
		% within group	6.0%	28.0%	6.0%	48.0%	6.0%	6.0%	100.0%
Yates Chi square value: 73.827			**P value: <0.001****						

Match/Mismatch	***N***	***%***
Ideal match	37	74 %
Mismatch	13	26 %
Total	50	100 %

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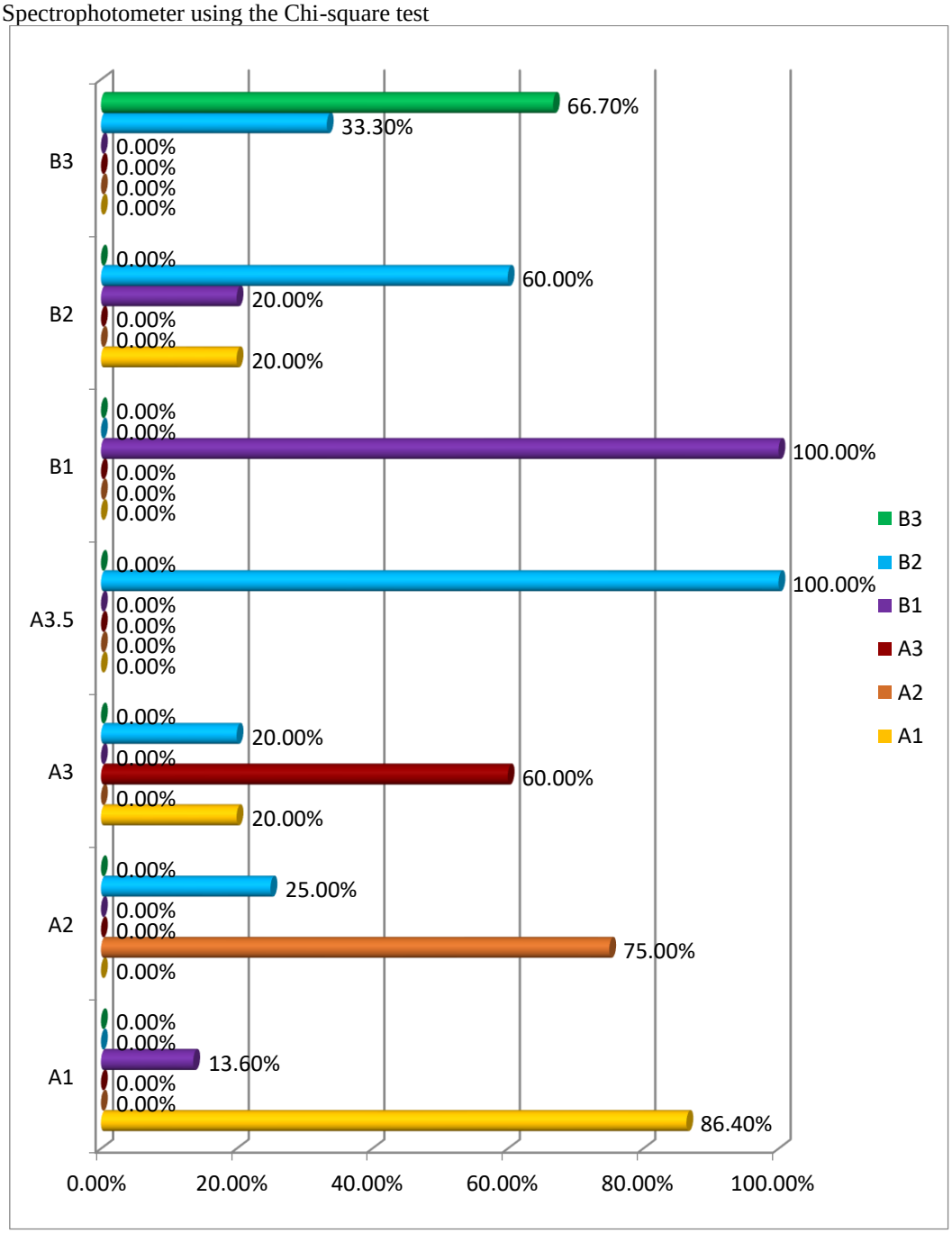
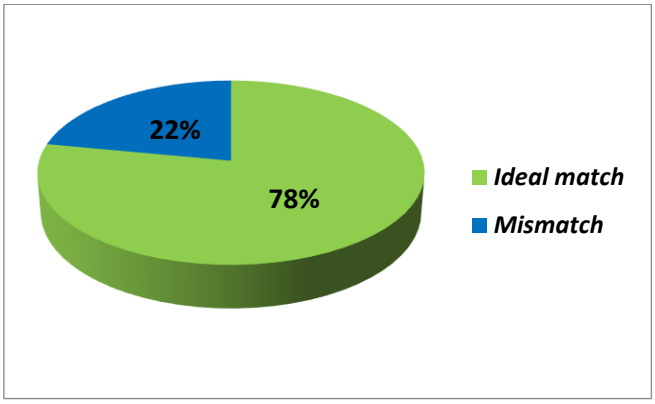
Accuracy of the Vita Classic shades of extracted teeth obtained from the Intraoral scanner compared to the Vita Easyshade Spectrophotometer using the Chi-square test



Pie diagram of the accuracy percentage of the match/mismatch for the Vita Classic shades of extracted teeth obtained from the Intraoral scanner



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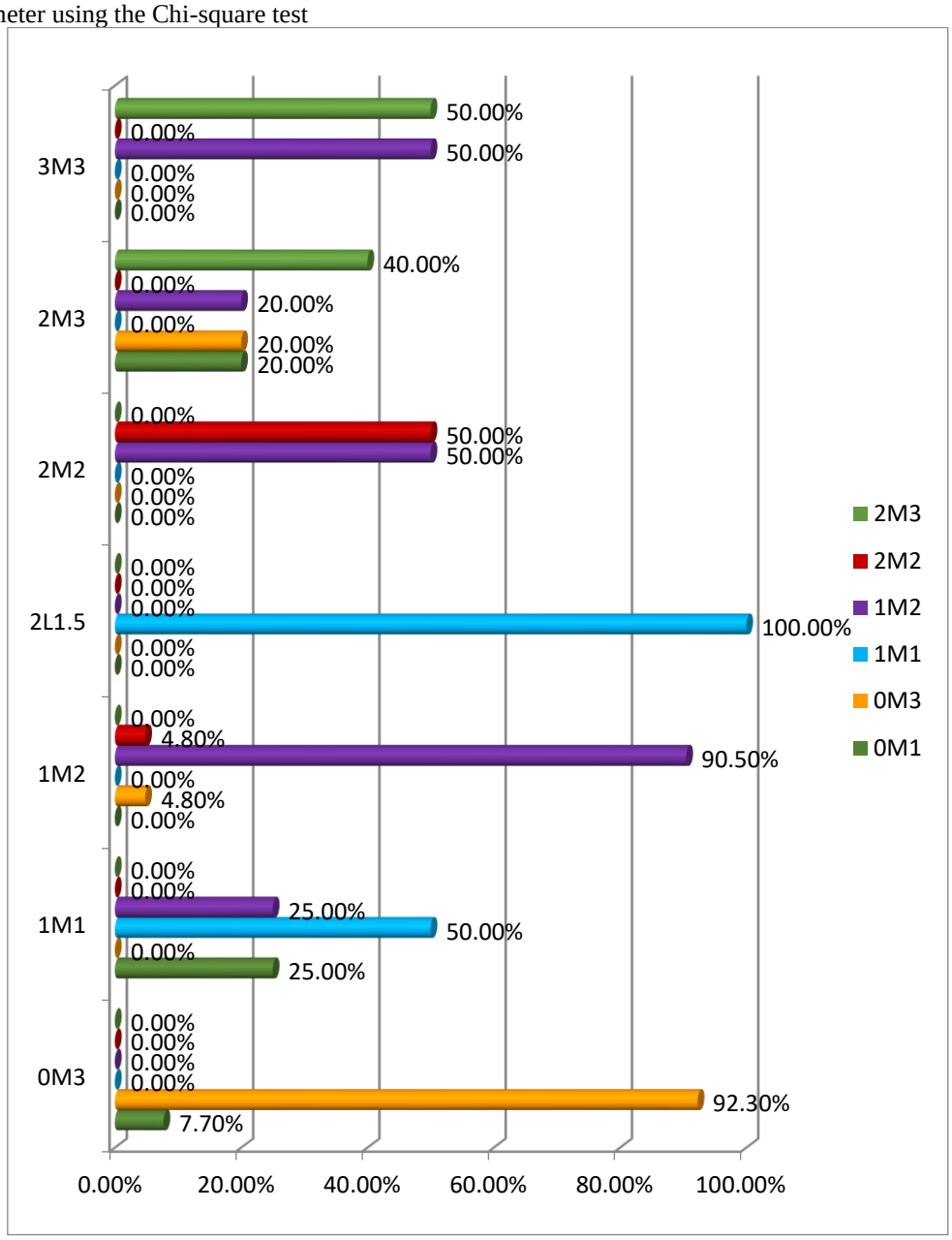
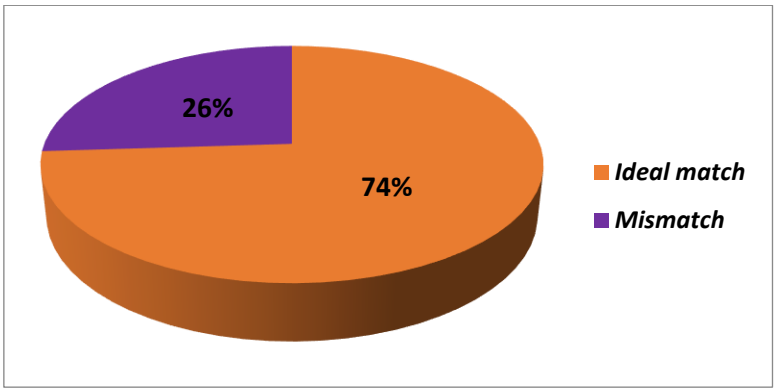
Accuracy of the 3D Master shades of extracted teeth obtained from the Intraoral Scanner compared to the Vita Easyshade Spectrophotometer using the Chi-square test



Pie diagram of the accuracy percentage of the match/mismatch for the 3D Master shades of extracted teeth obtained from the Intraoral Scanner



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Intraoral Scanner Readings (Test Group)

Descriptive statistics for the Vita Classic shades of extracted teeth recorded on the Intraoral Scanner (Test Readings) to determine the repeatability

Average Repeatability% (Mean) = 4580/50 = 91.6%

Descriptive statistics for the 3D Master shades of extracted teeth recorded on the Intraoral Scanner (Test Readings) to determine the repeatability

Average Repeatability% (Mean) = 4740/50 = 94.8%

RESULT

1. The accuracy of tooth shade selection on extracted teeth of the Intraoral Scanner compared to the Spectrophotometer measurements for the Vita Classic shade tab was 78%, which was statistically significant.
2. The accuracy of tooth shade selection on extracted teeth of the Intraoral Scanner compared to the Spectrophotometer measurements for the 3D Master shade tab was 74%, which was statistically significant.
3. The repeatability of tooth shade selection on extracted teeth of the Intraoral Scanner was 91.6% for the Vita Classic shade tab.
4. The repeatability of tooth shade selection on extracted teeth of the Intraoral Scanner was 94.8% for the 3D Master shade tab.

DISCUSSION

The form, function, and esthetics of a restoration are of prime importance in its success. Visual analysis using a commercially available shade guide is the most commonly used method to select shadebut it can be extremely unreliable and inconsistent.[10,11]This is because shade selection is based on visual perception and is the outcome of a variety of physiological and psychological responses and can differ according to the environment.[12,13]

A study done by **Xiaojie W, Boriana M, Arndt K, Stefanie H, Ulrich B(2011)[14]** revealed structural recovery of eroded enamel after storage in artificial saliva for 24 hours.

Ambient light conditions were used for shade determination in both the methods in order to improve the accuracy of the shade matching obtained clinically.[15]

The middle third of the labial surface of the tooth reflected tooth color most accurately, as the incisal third is often too transparent and the gingiva in the cervical third disperses the reflected light, thus distorting the tooth color.[16,17]

The extracted tooth was embedded lingually, from its apical root tip upto the middle third of its coronal structure on a white wax block for the purpose of stabilization while scanning and determining shade and was placed directly over the 18% reflectance gray card. The white color of the wax block and the gray card represent neutral targets as their red, blue and green values are equal. It represented the middle tone used for exposure determination, halfway between pure black and pure white. Since the gray card had definite values, the software also interpreted it as gray, thus eliminating the color cast of the whole picture and promoting accurate color caliberation.[18]

As per the manufacturer's instructions, the Tooth Area mode in the Vita EasyshadeAdvance 4.0 helps to determine the base shade in the middle area of a natural tooth.[19]

The purpose of this study was to verify the accuracy of shade matching of the TRIOS 3[20], using as control the Vita EasyShade Advance 4.0 which demonstrates superiority in color selection.

The accuracy of the Vita Classic and 3D Master shade of extracted teeth obtained from the Intraoral Scanner compared to the Vita Easyshade Spectrophotometer using he Chi-square test[21] was 105.771 and 73.827 respectively. The P value, therefore calculated for both was less than 0.001 which inferred a statistically significant difference. The Vita Classic and 3D Master shade tab function for the Intraoral Scanner had an ideal match of 78% and 74% respectively.These results could be because the Vita Classic shade tab gives a single shade whereas the 3D Master shade is a combination of two base shades.

From this we concluded that the Vita Classic shade function of the Intraoral Scanner gave us an accuracy which was 4% higher than the 3D Master shade function. Another explanation for this result could be that the Intraoral Scanner primarily detected the Vita Classic shades. This could be the reason for the Intraoral Scanner being unable to detect the entire range of the 3D Master shades. A lower accuracy result for the Intraoral Scanner could be due to faulty readings obtained because of the probe not covering the middle third of the labial tooth surface in question or due to computer or software malfunctions. Accuracy of color measurement is also affected by the phenomenon of edge loss because some emitted photons are lost and are not detected by the device.[22]

The repeatability for the Vita Classic and 3D Master shade tab of the Intra-oral Digital Scanner was found to be 91.6% and 94.8% respectively.

The 3D Master shade tab of the Intraoral Scanner had a better repeatability than the Vita Classic or the 3D Master shade tab of the Vita Easy Shade Advance 4.0. A study done by **Ramin et al[23,24]** of the comparison of shade match compatibility between Vitapan Classical and 3D Master Shade Guide systems by dental students, concluded that significant differences were obtained between the two shade guide systems, with the 3D Master system exhibiting higher repeatability compared to the Vitapan Classical system. The advantages of the 3D Master shade guide system include ease of use and stepwise nature of procedures and separation of color components in different stages of color/shade

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selection, compared to the Vitapan Classical system. **Bayindir et al[25]** evaluated the errors of shade guide systems and concluded that 3D Master shade guide system has lower visual errors compared to Vitapan Classical system. **Hassel et al[26]** compared the clinical efficacy of Vitapan Classical and 3D Master shade tabs and reported that crowns undergoing color selection with 3D Master could be cemented without any shade modification. **Juan et al[27]**compared the repeatability of the visual method to that of the intraoral scanner in dental shade matching and reported a repeatability of upto 90% for the intraoral scanner. The results of this study confirmed the superiority of the Intraoral Scanner over the visual method in terms of repeatability in dental shade matching.

The "Shade Detection" feature recently introduced by TRIOS 3 simplified the entire clinical process with an improvement in time and cost efficiency, creating a better patient experience, requiring a single scan. The results of this study have shown that the Shade Detection feature requires improvements.

Several factors including surface texture, translucency and the color of surrounding environment make shade selection for natural teeth more difficult. To overcome the discrepancies of shade selection experienced due to commercially available shade guides, instruments such as spectrophotometer and colorimeter, digital cameras were introduced in dentistry which enabled clinicians to perform an objective analysis and compare the shades.[3]

It is important that the monitor and scanner are in agreement, so the colors in the images scanned do not shift when the images appear on the screen. Therefore, the Intraoral Scanner showed a lower accuracy as compared to the Spectrophotometer which is considered as the gold standard for measuring tooth shade.

The present study evaluated the accuracy and reproducibility of the intraoral scanner, in comparison with the spectrophotometric shade-matching. The results have shown a moderate accuracy for the intraoral scanner. In a in vivo study done by **Culic et al[28]**showed that the intraoral scanner may not be used as an accurate method of shade selection, considering significant differences in shade tab codification with the spectrophotometer. However, the study has demonstrated that the Vita 3D Master shade guide presents more satisfactory results in terms of its repeatability compared to the Vita Classic shade guide. Further studies are needed to validate the results obtained from this study in terms of the methods commonly used, for an optimal shade matching, that meets the patient needs.[29]

The results support the use of a scanning and color measuring computer-based system in dentistry. The further development of such systems for clinical use would be warranted and could serve as a valuable tool for material selection and restoration design, particularly in aesthetic, restorative dentistry.

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Figures

Fig. 1: Extracted teeth

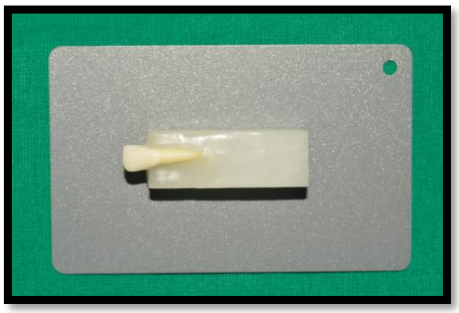

Fig. 2: Tooth specimen placed on an 18% Reflectance Gray Card

Fig. 3: Tooth shade determination using the Vita Easyshade Advance 4.0

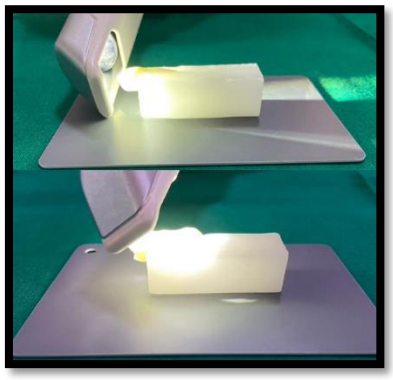

Fig. 4: Scanning the tooth using the Intraoral Scanner