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COMPARISON OF THE INTRAORAL SCANNER AND VISUAL SHADE MATCH ACCURACY IN SHADE DETERMINATION

Moustafa Mahmoud Elgendy [1*] BSc, Yousreya Atteya shalaby [2] PhD, Noha Morsy [3] PhD

ABSTRACT

INTRODUCTION: Reproducing a restorative material can be challenging due to the need for accurate shade identification and color replication. Currently, digital intraoral scanners (IOS) and visual shade guides can accurately evaluate the exact color of natural teeth.

OBJECTIVE: This clinical trial utilized a randomized, double-blinded, controlled cross-over design to evaluate the accuracy of shade matching, and compare the Medit i700 IOS intraoral scanner with visual shade determination.

MATERIAL AND METHODS: The study selected 44 teeth from participants who had at least one healthy and undamaged maxillary central incisor based on a 5% alpha error and 80% study power.. A proficient examiner utilized a 3D-Master shade guide to ascertain the hue of the middle section of the upper central incisor. The Medit i700 intraoral scanner accurately captured images of the maxillary anterior teeth, following the guidelines provided by the manufacturer. The software of the scanner will utilize on-screen tools to choose shades. The most suitable hue was determined, and the E_{00} value was calculated to assess the extent of color variation in each experimental group.

RESULTS: The 3D-Master shade guide displayed a visually noticeable color difference (DE>3.7) of 34.1%; however, the Medit i700 revealed a color difference of 61.4%. The P value (0.080) showed no significant difference between the 3D-Master shade guide and Medit i700. The median of triangle E was determined to be 3.86 for the Medit I 700 IOS and 0.00 for the visual shade 3D-Master. The P value (0.548) showed no difference between the 3D-Master shade guide and Medit i700.

CONCLUSION: The Medit i700's precision in tooth shade was considered in comparison to the visual shade made using the 3D master shade guide.

Key terms: Accuracy, Digital intraoral scanner, Visual shade selection, Shade guide, and 3D-Master.

1-Resident doctor of Fixed prosthodontics. Department of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Egypt.

2-Professor of Fixed prosthodontics. Department of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Egypt.

3-Lecturer of Fixed prosthodontics. Department of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Egypt.

Corresponding author:
mostafaelgendy13.me@gmail.com

BACKGROUND

Precisely identifying the hue and replicating color can pose difficulties when handling a restorative substance. Moreover, patients frequently possess elevated expectations regarding the outcomes of the restorative procedure. When utilizing traditional shade recommendations, the process of choosing a visual shade is based on personal judgment and influenced by factors such as lighting conditions, the person observing, and the object being observed. Manufacturers have created shade selection devices that offer unbiased and quantifiable shade values. (1) The aesthetic success of permanent restorations is greatly dependent on precise shade matching. In addition, patients frequently have elevated expectations regarding the outcomes of the restorative procedure. Precise and meticulous color selection is essential to achieve a visually appealing restoration. In dentistry, shade selection can be achieved through instrumental methods such as spectrophotometers, colorimeters, and intraoral scanners, or visual assessment using a shade guide. (1, 2) Shade detection using visual methods entails selecting the shade tab from a shade guide that closely matches the color. Shade detection using visual methods entails selecting the shade tab from a shade guide that closely matches the color. Vita Zahnfabrik produces the extensively utilized Vita Classical shade guide, which predominantly derives its coloration from the natural hues of teeth. Other shade guides available are Chromascop by Ivoclar Vivadent AG, Bioform by Dentsply Sirona, and Vita 3D-Master (VM) by Vita Zahnfabrik. The Vita 3D Master shade guide is a reliable and trustworthy tool for shade selection, as it offers a wider range of shade samples. Visual determination is commonly used in modern clinical practice. Nevertheless, the outcomes are exceedingly subjective and susceptible to a multitude of factors, such as one's background, lighting conditions, the practitioner's level of skill, and age. Experts are now shifting towards instrumental shade selection methods to improve the fairness of shade matching and accurately determine the color of a tooth. Experts have recently enhanced intra-oral scanners by incorporating a built-in module for color determination. The addition of the new integrated color determination module enables the optional capture of tooth color while taking a digital impression, leading to improved efficiency and cost reduction (3). Conversely, when utilizing an intraoral scanner, the selection of shade is contingent upon the precise manner in which the scanner captures the image. The sensor's capacity to emit and gather light can influence the result. As a result, the accuracy of the shade selection of the intraoral scanner can be compromised due to factors such as manipulation, the type of intraoral scanner being used, and insufficient color analysis software. Additionally, the intraoral scanner can scan a significant surface area, however, it is susceptible to inaccuracies resulting from the prevailing lighting conditions in its surrounding area (4). This study aims to evaluate the accuracy of shade matching using the Medit i700 intraoral scanner compared to visual shade determination with the 3D-Master shade guide. The null hypothesis was that there would be no significant difference in the accuracy of shade matching between the two methods.

MATERIALS AND METHODS

This clinical trial utilized a randomized, double-blinded, controlled cross-over design to compare different conditions within the same subjects. The study was conducted according to the Standards for Reporting of Diagnostic Accuracy Studies (STARD) criteria. The participants were selected from the outpatient clinic in the Conservative Dentistry Department at the Faculty of Dentistry, Alexandria University. The shade selection was one component of the conventional treatment procedures administered to the patient. The sample size using calculated a 5% alpha error and 80% study power. Forty-four teeth from the participants were included in the sample. The inclusion criteria for patient selection consisted of individuals with a minimum of one vital maxillary central incisor, aged between 20 and 25 years, and an oral hygiene index (OHI) score of less than 2. The inclusion criteria for patients did not allow those with pre-existing tooth decay, dental restorations, teeth whitening, or orthodontic treatment specifically related to the maxillary central incisors. Additionally, patients with congenital or acquired tooth discoloration, and misaligned or non-vital maxillary anterior teeth were excluded. An independent operator used research devices and a computer to prepare a list and randomly select the shade for each participant using closed envelopes. Research Methods The pre-established eligibility criteria led to the selection of a total of forty-four participants for this study. A single proficient examiner (5) conducted the shade selection. The measurements were conducted in a designated treatment room with a window to replicate daylight conditions as closely as possible. During the shade matching process, the patient was instructed to remain seated in the same chair, with their mouth slightly ajar, their tongue relaxed, and their body in a stationary position. This occurs because applying pressure to the tongue on the front part of the upper jaw can lead to inaccurate measurements caused by the transparency of the incisal teeth (6). Visual shade selection: The patient performed oral hygiene measures to enhance the precision of shade determination the patient was advised to abstain from using lipstick and to steer clear of excessively vibrant clothing. a Smile Light lamp was used with a color temperature of 5500 K, which closely resembled natural light, in conjunction with a gray bib for each instance. Under natural daylight conditions, the examiner documented the tooth's hue. The examiner recorded the tooth's hue by evaluating its color in the central region against the 3D-Master shade guide (Fig.1). The examiner promptly chose the color to minimize eye strain. the color shade was selected using intraoral scanners, specifically Medit i700, for instrumental purposes. A single examiner conducted each scan. The examiner positioned the patients in a reclining position on the dental chair, facing the window, for the scans. The illumination was deactivated in the dental chair. After filling out the digital datasheet and documenting personal details, we chose the diagnostic cast icon. The Medit i700 intraoral scanner was used to scan the maxillary anterior teeth, adhering to the manufacturer's guidelines (Fig. 2) the scanned object was positioned at the center of a designated data collection area to establish a perfect sphere encompassing the object. During the procedure, the examiner demonstrated smooth and continuous movement, ensuring that the tooth remained centered and at a consistent distance (7). The examiner placed the camera 5 to 30 mm away from the surface for scanning. It moved in a straight line across all the incisal and palatal surfaces before moving to the labial surface. This enabled the capture to conclude at the original position, minimizing spatial distortion and avoiding a unidirectional error (7). Before conducting a scan on a new subject, the scanner underwent calibration. The operator can reveal the 3D-Master tooth shades, measured at the middle third of the labial surface, by hovering the arrow over the tooth after clicking the tooth shade icon. This process occurs after the meshes have been refined. Choosing the optimal match (reference hue) We used two tooth shade determination methods, one visual and one instrumental, to assign two 3D-Master shade tabs to each tooth. The examiner, accompanied by two seasoned dentists, chose one of the three tabs that they deemed to be the most precise match to the patient's examined tooth. This selected tab will serve as a reference shade for assessing the accuracy of shade selection. Choosing the optimal match (reference hue) We assigned two 3D-Master shade tabs to each tooth, using two methods for determining tooth shade: one visual and one instrumental. The examiner, accompanied by two seasoned dentists, chose one of the three tabs that they estimated to be the most precise match to the patient's examined tooth. We then used this chosen tab as a reference shade to assess the accuracy of shade selection (Fig 3) (6).

Evaluation of the accuracy in choosing the suitable hue The tooth color data obtained from the 3D-Master shade reference was converted using the CIE colorimetric table values provided by Bayindir et al (8). The ΔE00 was computed by utilizing the CIE Lab values for each technique to ascertain the tooth's closest shade match. The CIE L*a*b* system utilizes three coordinates, specifically L*, a*, and b*, to precisely define a particular color. The chromatic properties, specifically Chroma, and hue, along the red-green and yellow-blue axes, are determined by the coordinates a* and b*, respectively. The brightness, on the other hand, is determined by the coordinate L*. The numerical range spans from 12 to 14. The CIEDE2000 formula computes an ΔE00 value, which quantifies the Euclidean color disparity between two samples. ΔE measures the extent to which the selected color is deemed acceptable and distinguishable (8). Reports indicate that a color difference below 6.8 is deemed acceptable. When it comes to being able to see and distinguish between colors, the human eye can do so when the color difference (ΔE) is 3.7 or higher in normal conditions, and 1 or higher under controlled conditions (9, 10). Additionally, the frequency at which the assigned tab was selected as the best match was calculated for each shade selection method. Engagement the most up-to-date CIEDE 2000 equation to compute the ΔE00 discrepancy between the optimal matching shade and the shades chosen by each group (visual shade by 3D-master and Medit i700 IOS).

$$\text{CIEDE 2000}: \Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}}$$

Figure 1: Visual shade selection by 3D-Master shade guide for middle third of upper right incisor

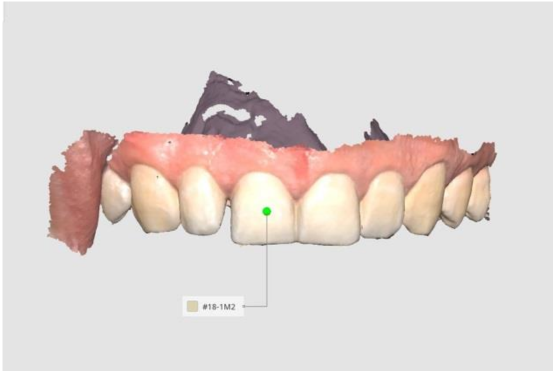

Figure 2: Screenshot of shade selection of middle third of the labial surface of upper left central incisor by Medit i700 IOS.

Figure 3: Best shade match selected for Middle third of upper right central incisors

RESULTS

Each shade selection was verified through the shade-matching process. The study encompassed a combined total of forty-four central teeth, distributed evenly on both the right and left sides. The 3D Master visual shade guide and the Medit i700 were utilized to perform shade selection. Afterward, the Best Match shade was selected from a total of nine shades, with three shades from each of the three groups. Table 1 and Figure 4 present the precise ratios of each chosen shade in the two groups and the most appropriate correspondence.

ΔE_{000} between 3D-Master shade guide and Medit i700: In the 3D-Master shade guide group, the Median was 0.00 so it is close to the best match shade and more accurate than Medit i700, in which the median was 3.86, in the selection of shade.

P value (0.548) showed no statistically significant difference between the 3D-Master shade guide and Medit i700. (Table 2).

Color difference (DE) when teeth shades recorded by 3D-Master shade guide and CS3700 and Medit i700: In the 3D-Master shade guide group, the color difference was below 3.7 in 65.9% and above 3.7 in 34.1%, and in the Medit i700 group, the color difference was below 3.7 in 38.6% and above 3.7 in 61.4% (Table 3).

The P value (0.080) showed no statistically significant difference between the 3D-Master shade guide and Medit i700

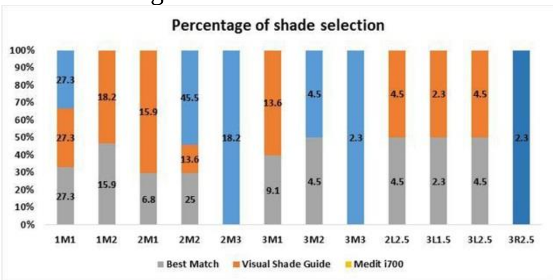

Figure 4: Percentage of shade selection

Table 1: Percentage of shade selection as recorded by each shade-matching process

	Best Match (n=44)	**Visual Shade Guide (n=44)**	**Medit i700 (n=44)**
1M1	12 (27.3%)	12 (27.3%)	12 (27.3%)
1M2	7 (15.9%)	8 (18.2%)	0 (0%)
2M1	3 (6.8%)	7 (15.9%)	0 (0%)
2M2	11 (25%)	6 (13.6%)	20 (45.5%)
2M3	0 (0%)	0 (0%)	8 (18.2%)
3M1	4 (9.1%)	6 (13.6%)	0 (0%)
3M2	2 (4.5%)	0 (0%)	2 (4.5%)
3M3	0 (0%)	0 (0%)	1 (2.3%)
2L2.5	2 (4.5%)	2 (4.5%)	0 (0%)
3L1.5	1 (2.3%)	1 (2.3%)	0 (0%)
3L2.5	2 (4.5%)	2 (4.5%)	0 (0%)
3R2.5	0 (0%)	0 (0%)	1 (2.3%)

Table 2: Comparison of ΔE_{000} between the color assessed by 3D-Master shade guide and matched by Medit i700 intraoral scanner.

	3D-Master shade guide	**Medit i700 (n=44)**
Mean ±SD	1.58 ±2.15	3.08 ±2.65
Median	0.00	3.86
Min – Max	0.00 – 5.35	0.00 – 7.45
P value†	0.548	

*Statistically significant difference at p value≤0.05, †Friedman test

Table 3: Visually perceptible color difference (DE>3.7) when teeth shades recorded by 3D-Master shade guide and best match values with Medit i700 intraoral scanners.

	3D-Master shade guide	**Medit i700 (n=44)**
DE<3.7	29 (65.9%)	17 (38.6%)
DE>3.7	15 (34.1%)	27 (61.4%)
P value†	0.080	

* p value ≤ 0.05 indicates a statistically significant difference., †Cochran's Q test

DISCUSSION

The null hypothesis of this clinical study stating that there would be no significant difference in the accuracy of shade matching between Medit i700 intraoral scanner and visual shade determination with the 3D-Master shade guide was accepted. Studies have shown that 3D-Master shades are accurate tooth shade alternatives (11, 12) and reduce the need for final restorative correction. The Medit i700 intraoral scanner and visual shade selection were compared to the best shade match in this study. According to previous studies, visual shade selections and Medit i700 wireless measurements differed, disproving the research hypothesis. The 3D-Master shade tabs are the best visual tool for shading examined teeth. Medit i700 followed closely. Research suggests that women may match teeth better than men (13), possibly because men (8%) have more color deficiencies than women (0.5%) (14). However, multiple studies show that male and female color-matching results are similar (15, 16). We used two females and one male dentists (aged 20–35) as examiners to determine the best shade match.

The speed and capacity of digital technology have improved dentist-technician-patient communication (3). Previous studies have shown that digital methods can help determine tooth color. However, these methods are expensive. Despite being the most accurate method for determining tooth color, this study found that the tooth colors did not align (17). In the Medit i700 study, 34.1% of tooth evaluations met ideal tooth color criteria. This significant disagreement may be due to the Medit i700 device's different technologies and the visual method used to identify natural tooth color (7). Triangulation and bidirectional reflectance distribution function (BRDF) generate 3D-colored images in the Medit i700 IOS. BRDF can detect shades from different angles and paths regardless of tooth texture, structure, or curvatures. The Medit i700, with triangulation scan technology, had the highest accuracy and fastest scanning time (18). A study compared the mean color difference (ΔE) between Medit I 700 IOS and the visual shade 3D-Master to the best shade match. The calculated values were 3.08 and 1.58. Median values are 3.86 and 0.00. A clinically meaningful distinction between two colors is determined by the color difference value ΔE. According to Kashaya et al. (19), both the practitioner and calculation formula can impact the clinical manifestation of ΔE values (20, 21).

Multiple studies have reported acceptable color disparities between 2.72 and 6.8 (22, 23). Medit I 700 IOS's color difference is significantly reduced by the widely accepted acceptability threshold of 3.7. This indicates low-to-medium Medit I700 IOS accuracy. We converted the 3D-Master shade to CIE model (L*, a*, b*) coordinates using the Bayindir et al. table (8). The 3D-Master lacks color and has a large tab gap. Different authors use different empirical methods to determine values (24, 25). Though approximating, the table conversion is the only way to convert shade detection by the human eye and the instrumental method (Medit I 700) into mathematical L*a*b* values.

Intraoral scanners are becoming more accurate at taking digital impressions (26). Their colorimetric analysis is unsatisfactory due to the limited color options and significant discrepancies compared to visual shade selection. According to previous research, they should not be used to determine the restoration's hue (27). This study examined shade under controlled clinical conditions to reduce shade measurement errors. Instead of measuring extracted teeth or ceramic specimens with a light box, clinical study settings provided a natural environment for shade measurement. In this study, central incisors were shaded for ease of access and to reduce oral structure shadow errors. The middle third of the teeth is best for shade selection to match natural color. The gingival margin can affect the cervical third, and the incisal third's translucency may not match the tooth's color. Translucency and curvatures of natural teeth, environment, and patient position can affect shade-matching devices in vivo. For accurate color difference ΔE calculation, a conversion table is required as the scanner cannot generate accurate L, a, and b values. Laboratory technicians analyze data to build tooth restorations with ceramic powders. Technician skill and ceramic thickness or composition affect the outcome (28, 29). The technician's workflow and switch to the 3D-Master reference can cause color discrepancies between the restoration and the original shade. The innovative eLab technique (30) accurately determines the ceramic powder ratio based on the tooth's (L*, a*, and b*) coordinates to overcome the limited color references (27). Visual and intraoral scanner color differences were statistically significant. A previous study found intraoral scanners captured colors brighter than the human eye (27). In this study, the Medit i700 scanner did not have this capability. The differences between the studies are due to the scanner generations used. Newer intraoral scanners are more precise and have distinct characteristics, according to research (31). According to research (27), intraoral scanners capture fewer colors than visual shade 3D masters. Contrary to previous findings, intraoral scanners did not improve shade-matching accuracy (32). The scanner's acquisition procedure and the sensor's light detection affect IOS shade selection. This makes the IOS shade selection process more susceptible to manipulation errors, which vary by IOS type and color analysis software quality. The process scans a larger area, increasing error risk. Furthermore, environmental light can affect iOS performance (32).

The study did not account for the skill level of the operator using the medial i700, which could influence the outcomes. Additionally, environmental conditions that impact color perception were not controlled. Additional studies are needed to address these limitations and explore further advancements in IOS technologies to improve both the accuracy and reliability of digital shade matching.

CONCLUSIONS

1.The Medit i700's tooth shade accuracy was subpar to moderate compared to the 3D master shade.guide.

2. Intraoral scanners' color shade accuracy depends on their software and technique. 3.Overall, while the 3D Master shade guide demonstrated greater accuracy, the difference between the two methods was not statistically significant.

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