

Comparative Evaluation Of Accuracy And Repeatability Between Digital And Visual Methods Of Shade Matching Using Emax Crowns; An In-Vivo Study

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DOI: 10.47750/pnr.2022.13.S09.378

Abstract

Statement of problem: Visual method of shade selection is subjective and a cause of concern for clinicians. Different measurement devices have been developed to assist in shade selection and to achieve acceptable esthetic results. However, there is a lack of consensus to which method of tooth shade selection provides more predictable results.

Purpose: The purpose of this clinical study was to compare the accuracy and repeatability of different visual and digital methods for dental shade matching.

Material and methods: Visual shade matching was performed using 3D-MASTER with 29 tabs; (VITA Zahnfabrik) without the aid of a light-correcting device and digital method using intraoral scanner (TRIOS; 3Shape A/S). spectrophotometer (VITA Easyshade Advance 4.0; VITA Zahnfabrik) was used as a control in this study for color shade matching. The digital and visual methods were repeated 3 times to determine repeatability. Shade-matching sessions for each method were performed under natural sunlight on the middle third of the maxillary right central incisor of 20 participants. The Chi square test statistical test was used to assess the reliability of each method.

Results: Digital methods were equally accurate to visual methods. Repeatability variable and lab communication was better with Intraoral Scanner as compared to Visual method of shade selection using 3D MASTER Shade guide.

Keywords- Intraoral digital scanner, 3D master, Shade matching, E-MAX crowns.

Introduction: Esthetics in dentistry is concerned with the appearance of the dentition as achieved through its arrangement, form, and color. It is the prime concern for the patients, and the most crucial aspect of obtaining an excellent

esthetic result is determining the optimal shade for prosthetic reconstruction. The shade is of significance when patients judge the quality of the restoration, especially in the anterior region. The ideal shade is obtained from the natural, neighbouring teeth. There is no golden standard for specific tooth shade evaluation, and most dentists and dental technicians use colour tabs for the initial ceramic work. Accurate colour reproduction. Despite the limitations of visual assessment, the human eye is very efficient in detecting even slight differences in the colour between two objects. Visual shade matching is subject to variables such as age, sex, experience, type of scale used, different degrees of light exposure, eye fatigue, and physiological variables such as colour deficiency, which may also lead to inconsistencies.ⁱ Thus, for an in vivo validation of a new shade-determining device, a comparison to the conventional, visual method for the best shade match could be used. A high number of shade-determining devices has been introduced to make shade selection more accessible and more accurate, allowing the dentist to provide a better esthetic result of the prosthetic reconstructions. Light-correcting devices are available to minimize lighting interference and allow neutral clarity to assist the visual method of shade matching.

Intraoral digital scanners (TRIOS 3; 3Shape) 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 colourimeters or spectrophotometers is unclear. This study evaluates the reliability of an intraoral digital scanner (TRIOS Colour; 3Shape) in determining the tooth colour. A subjective visual method and the VITA Easy shade Advance were used as control in the study.ⁱⁱ

The main hypothesis was that the intraoral scanner would achieve higher repeatability than the visual method in dental shade matching. Other hypotheses were that the visual method would be influenced by ambient lighting, individual perception and the observer's experience.

Materials and Method: The study protocol was approved by the Ethics Committee of Bharati Vidyapeeth Dental College and hospital.

- 20 Patients were selected based on the inclusion and exclusion criteria as stated in the data. **(Fig 1)**
- Patients were verbally instructed about the study followed by written consent taken from the patient.
- In the first appointment diagnostic impressions were made using Irreversible hydrocolloid material (Zhermack Hydrogum Soft Alginate Powder) and poured in dental stone. (KalabhaiLabstone)
- In the second appointment crown preparations (for Emax crowns) were completed. **(Fig.2)**

Shade selection:

- White drapes were used in patients to attain neutral environment during the procedure.
- Blue drapes were used to reduce eye fatigue.
- Natural day light was used as the source of light for shade selection (CRI -100, colour temperature-6500°K)
- Shade selection for every patient was done at the same time of the day (11:30pm-2pm) by the same operator.
- Shade selection was done simultaneously using both the techniques post crown preparation.
- Patient was viewed at eye level and at arms length of the same operator. Shade selection was done on a moist tooth and on the adjacent tooth at the middle third of the tooth surface.
- Visual shade selection was performed using Vita 3D-Master shade guide with 29 tabs without the aid of a light-correcting device.
- While using the shade guide, the VALUE was determined first followed by CHROMA and then HUE.
- When selecting the value (lightness), shades were chosen from darker to lighter. This was followed by selecting one of the three shade samples to determine chroma. **(Fig 4)**
- The color tabs were held against the natural adjacent tooth to check whether it was yellow (left) or grey (right) for determining the hue.
- Patient's opinion in the shade selection was considered.
- This selected shade was further communicated to the lab for crown fabrication. **(Performed by the principal investigator)**
- An Intra oral scanner was used for shade selection [TRIOS; 3Shape] **(Performed by the scanner operator) (Fig 3)**
- Shade selection was done using digital Vita EASYSHADE guide, which was used as a control to compare the two above mentioned methods. **(Performed by another operator) (Fig 5)**
- Thus making the study double blinded.

Repeatability Assessment:

- The instrument as well as visual methods were repeated 3 times to determine the repeatability during the shade selection procedure and the parameter of repeatability were calculated then.
- The 3 readings were taken at an interval of 5 mins for every patient
- A digital impression was recorded by the digital scanner and conventional impression of the same tooth was made using Vinyl polysiloxane impression material (3M ESPE, soft putty, Germany) and light body (Express XT Light Body Quick; 3M ESPE) with stock metal impression tray and tray adhesive (3M, ESPE, VPS) by single step impression technique for working model fabrication. **(Fig 3)**
- Provisional crowns were fabricated chairside (direct technique) using PROTEMP Plus temporisation material. (3M ESPE) and cemented using RelyX Temp NE (3M ESPE).
- The two crowns were fabricated from the same lab, under similar conditions
- Layering- The thickness of each layer will be verified by the technician using the digital calliper and would be kept same for all the crowns.

Shade Evaluation:

- The shade matching was first done between the crown fabricated from the lab and the tab of 3D Master selected for shade matching to assess the correct lab communication.**(Fig7)**
- Shade matching sessions for the crowns fabricated by two different methods were performed under natural lighting.
- These two crowns (fabricated per patient) were used for comparative shade analysis without cementation of the crowns on the prepared tooth.
- The shade of middle third of the maxillary central incisor crown was compared against the natural adjacent tooth used initially for shade selection.
- Digital Vita shade guide that was used as a control in the study aided in determining the accuracy of both the techniques of shade selection.
- Patient's opinion regarding the same was also considered.
- After selecting an esthetically acceptable shade of the crown , the crowns were cemented on the prepared teeth

Fig 1: Case selection according to inclusion and exclusion criteria



Fig 2: Emax crown preparation for 2 different patients



Fig 3: Digital shade selection using Intraoral Scanner

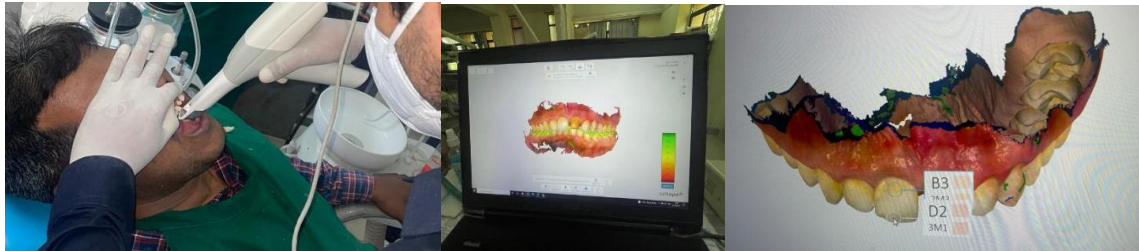


Fig 4: Visual Shade selection using 3D Master shade guide



Fig 5: Shade selection using Digital EASYSHADE (used as a control)



Fig 6: Emax crowns



Fig 7: Shade miscommunication between lab and operator for conventional lab communication



DIGITAL SHADE SELECTION VISUAL SHADE SELECTION



Fig: 8a

Fig: 8b

Here the visual shade selection is better than digital shade selection

DIGITAL SHADE SELECTION VISUAL SHADE SELECTION



Fig; 9a

Fig; 9b

Here the digital shade selection is better than visual shade selection

Results

Table 1: Comparative values of shade selected by 3M Trios Intraoral Scanner , Vita 3D Master Shade Guide and Digital Easyshade Vita Guide

SR. NO	PATIENTS	3M TRIOS INTRAORAL SCANNER (technique 1)	VITA 3D MASTER SHADE GUIDE (technique 2)	DIGITAL EASYSHADE VITA GUIDE (control)
01	1	4L2.5	5M3	5M3
02	2	3M2	3M1	3M1
03	3	3M2	3M1	3M1
04	4	2L1.5	2L1.5	2L1.5
05	5	4L1.5	2L1.5	2L1.5
06	6	4L1.5	4L1.5	4L1.5
07	7	2M2	2M2	2M2
08	8	1M1	1M2	1M1
09	9	2R1.5	3L2.5	2R1.5
10	10	2R1.5	2L2.5	2R1.5
11	11	3M3	4L2.5	3L2
12	12	3L1.5	4L1.5	4L1.5
13	13	2L2.5	2M2	2L2
14	14	2R2.5	3L1.5	3L1.5
15	15	2L2.5	3L2	2L2.5
16	16	3M2	3R1.5	3M2
17	17	4M3	4M3	4M3
18	18	2L2.5	3M3	2L2.5
19	19	3M1	2M2	2M1.5
20	20	4L1.5	4L1.5	4L1.5

Table 2: Repeatability assessment done using 3M Trios Intraoral Scanner and Vita 3D Master Shade Guide

SR. NO	PATIENTS	3M TRIOS INTRAORAL SCANNER (technique 1) SHADE VARIABILITY	VITA 3D MASTER SHADE GUIDE (technique 2) SHADE VARIABILITY
01	1	0	4
02	2	1	3
03	3	1	3
04	4	0	3
05	5	1	3
06	6	0	3
07	7	0	3
08	8	0	3
09	9	0	3
10	10	0	3
11	11	0	3
12	12	0	2
13	13	0	2
14	14	0	4
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16	16	0	2
17	17	2	3
18	18	1	1
19	19	1	2
20	20	0	2

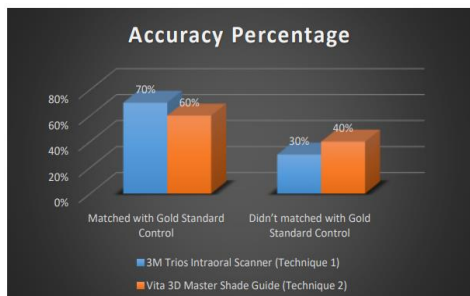
Table 3: Descriptive statistics of accuracy between 3M Trios Intraoral Scanner (Technique 1) and Vita 3D Master Shade Guide (Technique 2) in respect to CONTROL (Digital Easy shade Vita Guide)

	Matched with Gold standard control n (%)	Didn't matched with Gold standard Control n (%)
3M Trios Intraoral Scanner (Technique 1)	14/20 (70%)	6/20 (30%)
Vita 3D Master Shade Guide (Technique 2)	12/20 (60%)	8/20 (40%)

Table 4: Comparative statistics of accuracy between 3M Trios Intraoral Scanner (Technique 1) and Vita 3D Master Shade Guide (Technique 2) in respect to CONTROL (Digital Easy shade Vita Guide) using Chi square test

	Matched with Gold standard control n (%)	Didn't matched with Gold standard Control n (%)
3M Trios Intraoral Scanner (Technique 1)	14/20 (70%)	6/20 (30%)
Vita 3D Master Shade Guide (Technique 2)	12/20 (60%)	8/20 (40%)
Chi square test value = 0.440, p =0.507 (no statistical significant difference)		

p>0.05 – no statistical significant difference



Graph 1: Compiling and comparing the data representing the accuracies presented in table 3 and table 4

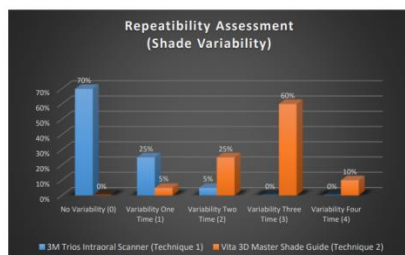
Table 5: Descriptive statistics of repeatability assessment (shade variability) between 3M Trios Intraoral Scanner (Technique 1) and Vita 3D Master Shade Guide (Technique 2) in respect to CONTROL (Digital Easy shade Vita Guide)

	3M Trios Intraoral Scanner (Technique 1)	Vita 3D Master Shade Guide (Technique 2)
No Variability (0)	14/20 (70%)	0 (0%)
Variability One Time (1)	5/20 (25%)	1/20 (5%)
Variability Two Time (2)	1/20 (5%)	5/20 (25%)
Variability Three Time (3)	0 (0%)	12/20 (60%)
Variability Four Time (4)	0 (0%)	2/20 (10%)

Table 6: Comparative statistics of repeatability assessment (shade variability) between 3M Trios Intraoral Scanner (Technique 1) and Vita 3D Master Shade Guide (Technique 2) in respect to CONTROL (Digital Easy shade Vita Guide)

	3M Trios Intraoral Scanner (Technique 1)	Vita 3D Master Shade Guide (Technique 2)
No Variability (0)	14/20 (70%)	0 (0%)
Variability One Time (1)	5/20 (25%)	1/20 (5%)
Variability Two Time (2)	1/20 (5%)	5/20 (25%)
Variability Three Time (3)	0 (0%)	12/20 (60%)
Variability Four Time (4)	0 (0%)	2/20 (10%)
Chi square test value = 33.33, p <0.001** (highly statistical significant difference)		

**p<0.001 – highly statistical significant difference



Graph 2: comparing the repeatability variables from Table 5 &6)

Discussion: The aim of this study was to compare both the above-mentioned techniques of shade selection and evaluate their accuracy and repeatability. This was achieved by comparing the accuracy and repeatability of shade selection done using a VITA 3D MASTER shade guide with a 3Shape TRIOS intraoral scanner. The accuracy of both the techniques was evaluated using VITA Easyshade V digital spectrophotometer as control. Evaluation of shade communication and reproduction by the lab was also done.

3Shape TRIOS is a well-established intraoral scanner in prosthetic dentistry and has recently added the tool of shade selection, therefore it was the instrument of choice for digital shade selection.

VITA introduced a new shade matching guide with a greater number of tabs than those included in the older Classic model; it is arranged in a more logical way and takes into account the three dimensions of color: hue, chroma, and value. With the implementation of these changes, the newly introduced VITA Toothguide 3D-MASTER showed better results than its predecessor, therefore it was chosen for visual shade selection.ⁱⁱⁱ

The VITA Easyshade V digital spectrophotometer was developed for precise, fast and reliable shade determination of natural teeth and ceramic restorations. Following were its features that made it a reliable shade selection device.

- Precise and reproducible tooth shade determination in seconds due to the latest measuring technology.
- Objective and accurate measurements, due to the LED technology that is unaffected by ambient conditions.
- Reliable and economical.

VITA Easyshade system was chosen as a reference for the method comparison in the study by Brandt ^{iv} due to its high measuring accuracy of 92.6% and 83,3% evaluated respectively in the in vitro study by Kim-pusateri et al. ^v and in vivo study by Paul et al. ^{vi}

In this study E-max crowns were preferred over Zirconium crowns because of their high aesthetic values for the anterior teeth replacement.

The study by Gehrke and co-workers ^{vii} used three regions (incisal, middle and cervical) across the tooth for color determination. The Trios® Color Shade system was able to measure all the various shades appearing all over the tooth surface, thus given a very detailed shade determination at the tested tooth. The reliability dropped, however, when the shade determination was extended to the periphery of the teeth. The incisal area was frequently translucent and affected by its background, and the scattered light from the gingiva frequently modified the cervical color ^{viii}. Thus, the middle third of the tooth was selected for shade determination, and this has also shown to be the site that best represents the color of the tooth in a study including a high number of teeth. Use of light correcting devices were avoided in this study to make the evaluation procedure more conducive to normal clinical setup.

The intraoral scanner not only recorded the shade for that particular tooth but also recorded the crown preparation. This entire data was shared with the lab in the form of an STL File. Thus there was a very efficient communication with the lab.

Conventional impressions were made using Putty and light body and shade selection done using 3D MASTER Vita Shade guide was conveyed to the lab by the operator. Thus the lab technician was completely dependent on the shade communicated by the operator without any visual perception of the tooth. This created some communication issues between the lab technician and the operator.

The observations obtained regarding the shade selection using the Digital Intra-oral Scanner, 3D Master Vita Shade Guide and Digital EASYSHADE were elaborated and compared in Table 1. Although the shade selection is done according to value followed by chroma followed by hue, the formula for the same is written as VALUE – HUE - CHROMA, for example -the shade 3M3 represents the value **group 3**, Hue **group M** and chroma **number3**. Thus, the shades by Intra Oral Scanner and 3D Master shade guide were recorded and compared against the shade recorded by Digital Vita EASYSHADE. The shade that were close or matching were highlighted for the study reference.

Similarly, the repeatability variable was calculated for each technique. Shade selection was repeated 3 times with an interval of 5 mins using visual method of shade selection using 3D Master as well as Intra-oral Scanner. This gave us a brief idea of fluctuation in the shade selection while recording it multiple (3) times. Precautions such as neutral environment with white background, blue drapes and 5 minute interval period was considered to control eye fatigue for visual method of shade selection. The variable values for the same were recorded in Table 2.

The accuracy shown by Intra oral scanner was 70% whereas accuracy shown by 3D MASTER was almost 60% (table 3 &4). This was considered as a statistically insignificant difference. The ability of the observers to choose a dental tone, because with practice and repetition observers would be expected to develop protocols allowing more precise and reproducible results over time. This is consistent with an earlier study by Kamimura E. that suggested the use of colour-matching instruments as a supplementary tool to improve the outcome of esthetic restorations. ^{ix} Other studies have suggested that tooth color selection using digital methods has greater agreement and effectiveness than visual methods. A similar study conducted by Yoon H ^x stated that using an intraoral scanner could not be the primary method for tooth color selection because of differences in color parameters with the colorimeter.

There were shade miscommunication issues with respect to 4 crowns out of 20 crowns for shades taken using 3D MASTER shade guide between the operator and the lab technician. Advantages of digital instrumental shade matching included more uniform communication between professionals and more accurate color selection. ^{xi} Such devices give control over external light conditions, and the photo-optic measurement allows color quantification. However, the high cost of the equipment still limits its more widespread use in clinical practice. Another factor that may have influenced the outcome of this study is operator skill and experience.

Concerning repeatability(table 5&6), the Trios color scored 70%. These results are comparable to those of Vita Easyshade: 76.6% measured respectively in the studies of Brandt et al.^{xiii} and Mehl et al^{xiii}. Repeatability is good with respect to newest generations of up to-date digital measurement systems. Repeatability was almost 0-10% with respect to 3D Master shade guide. This could be explained by the fact that layered structure of a tooth consisting of enamel, dentin, cement, and pulp, behaves differently when absorbing or reflecting different types of light, thus increasing the difficulty of shade matching. The true shade may lie about halfway between two colors. The apparatus needs to select one of them; hence, the only thing it can do is to select the one that is marginally better than the other. As there is always measurement noise, it will sometimes arbitrarily capture one color at one time, and another color at other times.^{xiv}

The main advantages of this study include the following:

- 1) The in vivo setting that is similar to the clinical reality of the population and does not require inferences or extrapolations, and
- 2) The controlled environment in which the study was conducted, which minimized the effect of external factors.

An innovative aspect of this study was the use of an Intraoral Scanner in the selection of color because, to our knowledge, this device has not been widely tested in the literature . In this respect, this study can be of benefit to the dental community.

Limitation of this study included

- 1) The light source used in the study was sunlight and no other light correcting devices were used. This could lead to error of subjective interpretation of shade. This can significantly affect the digital scanning protocol for different records made within varied duration.

Conclusion: In this in-vivo study, the shade selection using a digital intraoral scanner was compared to the visual method of shade selection using a 3D MASTER shade guide. The digital vita easy shade guide was considered as the control as well as the patient's opinion was also considered.

It was hence evaluated that the digital intraoral scanner showed slightly better results in terms of accuracy in shade selection as compared to the visual method using the 3D Master shade guide. This difference was statistically insignificant and did not establish any clinical conclusion regarding the better method of shade selection.

In terms of repeatability, the digital intraoral scanner showed much better and more significant results as compared to the visual method using the 3D Master shade guide

The lab communication of the selected shade was much easier and more efficient in the digital method using the intraoral scanner as compared to the conventional method of lab communication carried out for the shade selected using the 3D MASTER shade guide.

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