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Research Article

Impact of Digital Photography and Conventional Method on the Accuracy of Shade Matching in the Esthetic Zone (*In Vivo* Study)

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Abstract

Statement of the Problem: Accuracy of shade matching using conventional shade guides is a concern because color perception is highly subjective. Also, entirely relying on the digital method for shade selection can result in a deviation of color interpretation which may have an impact on the device's repeatability and accuracy.

Aim: To evaluate digital photography's accuracy in improving shade matching compared to conventional methods (visual shade guide and spectrophotometer).

Methods: 27 e. max CAD restorations were fabricated for 9 patients. Each received 3 restorations representing three groups for shade selection methods (visual, spectrophotometer and digital photography), to match with the shade of the contra-lateral/adjacent tooth. The patient satisfaction and shade matching were assessed by VAS and modified USPHS criteria respectively. The data obtained was statistically analyzed by Friedman's test performed in categorical data.

Results: In shade matching, there was a statistically significant difference between the three restorations. Restorations in digital photography group showed the highest prevalence of Alpha score followed by Visual 3D Master group then Vita Easyshade group. Group Vita Easyshade was the only restorations with Charlie score. No Delta scores were found. Regarding patient's satisfaction, there was a statistically significant difference between the groups with least satisfaction in the Vita Easyshade group.

Conclusion: Digital photography's impact in shade matching showed validity and reliability over the conventional methods and proved accuracy in terms of shade selection and surface characterization over the visual method. The spectrophotometer showed inconsistency in shade matching.

Keywords: Shade Selection; Shade Matching, Digital Photography, Spectrophotometer, Shade Guide

Introduction

Shade selection is a crucial part of esthetic dentistry and remains one of the main reasons for esthetic failure. Dentists should effectively deliver this information to the laboratory to create highly aesthetic restorations that seem indistinguishable from the surrounding natural teeth [1].

Several methods are available for shade selection. Visual shade matching is the conventional method, in which a commercially available dental shade guide is matched up with the desired tooth. Nevertheless, many factors contribute to perception errors such as different lighting variables and differences in color perception. These factors may alter the ability to achieve the desired results [1,2]. Therefore, to eliminate uncontrolled variables during color matching, instrumental tools have been developed. Spectrophotometric methods implement computer calculations based on color science, to allow quantitative evaluation. This method is considered objective and more accurate. Nevertheless, it is restricted to recording color, one point at a time, with absence of standardization of each reading. Moreover, its high price and relatively low performance concerning computer-aided devices are known drawbacks [2,3].

One of the most substantial tools in communicating with patients and dental ceramists is digital photography. Using a digital camera, for color interpretation, is now widely implemented. Photographic images permit the evaluation of multiple points. Also, they help describe surface texture and luster as heavy, moderate, and light to give various combinations for surface characterization [3,4]. Therefore, this study was designed to compare available systems to determine whether the digital camera would be an accurate tool for shade matching. The null hypothesis of this study was there would be no significant differences regarding patient satisfaction and shade selection between digital photography and conventional methods (visual shade guide and spectrophotometer).

Materials and Methods

This study was carried out in Fixed Prosthodontics Department clinics of Faculty of Dentistry, Cairo University, Egypt. Nine patients were involved in this study. Each received three restorations making a total of twenty-seven all-ceramic crowns. Only anterior teeth were included which represented a challenge in terms of shade matching and patient satisfaction [5].

Ethical consideration approval

The Research Ethics Committee of Cairo university approved this study (approval number 17726), an informed consent in the native language of the participants describing the treatment plan, images' publishing, and collection of results.

Registration

The trial was registered in the ClinicalTrials.gov under the registration number CEBC-CU-2017-07-17 on date July 2017.

Study design

This study was a triple blinded quasi-experimental research without randomization.

Inclusion criteria: 1) Age range from 20 to 40 years 2) Mild or moderate discoloration and coronal fracture more than half the tooth 3) Esthetics enhancement of previously placed crowns 4) Endodontically treated teeth 5) Presence of opposite occluding teeth [6].

Exclusion criteria: 1) Poor oral hygiene and compliance 2) Severely discolored teeth 3) Smoking habits 4) Excessive consumption of stain inducing drinks 5) Para-functional habits.

Sample size

A total sample size of twenty-seven crowns (nine patients) was sufficient, with power 80% and 5% significance level. The G power program was used for the sample size calculated [7].

Blinding

Trial participants, evaluators, and statistician were blinded.

All the clinical procedures were completed by one operator (the researcher). One experienced dental technician fabricated the crowns. Diagnosis, examination, as well as diagnostic photographs, were conducted by the investigator [6,8].

Dental prophylaxis was done before shade selection to remove all debris and stains. Also, it is essential to adjust the environment to be more favorable for shade matching [9].

The shade of the tooth was determined by three methods

First, visually, using the VITA 3D-Master shade guide (V3D) coinciding with the contra-lateral/adjacent (target) tooth under multiple light conditions: natural daylight, incandescent light, and color corrected light to avoid metamerism with the assistance of five expert prosthodontists that took Ishihara's test for color blindness [10]. All evaluators had no signs of color blindness.

The shade selection was carried out when natural daylight is most balanced with a visible light spectrum [10,11]. All bright colors were eliminated from the range of vision (lipstick, tinted eyeglasses). Clear glaze* was used on the shade tab and the natural tooth to keep them hydrated [12]. The patients' mouths were 40 cm away and at the same level from the evaluator's eyes. Shade tab was situated in the same plane as the target tooth where the incisal third of the shade tab was perpendicular to the incisal portion of

the target tooth. Both tooth and tab had similar neutral gray background[**]. Figure 1 shade was selected in 3 points (incisal, middle, and cervical) [10,11]. There was no time limit for this procedure; however, the evaluators were requested to rest by staring at a neutral grey zone every ten seconds [10,14].

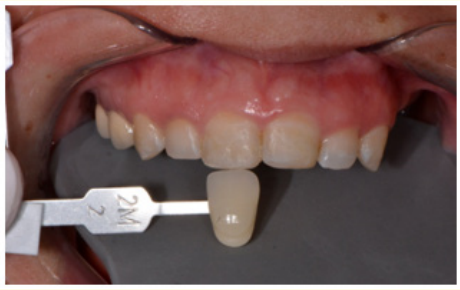

Figure 1: Shade selection under natural day light.

The color corrected light Smile line has a color temperature of 5,500K, a color rendering index (CRI) of 92 and situated about 10 cm away from the target tooth [10]. The evaluators were asked to look in the see-thru rectangular window of the color corrected light while standing in front of the target tooth holding the shade tab [15] (Figure 2).

Figure 2: Shade selection using color corrected light.

After the shade selection was achieved, a shade map drawing was sent to the lab [16] (Figure 3).

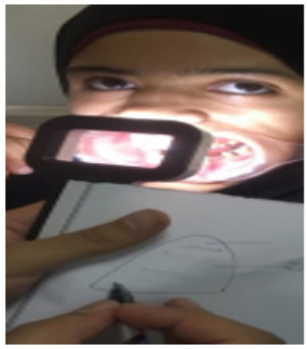

Figure 3: Shade mapping.

Second group, the shade was selected with Vita Easyshade V spectrophotometer [17][*] (VE). After placement of the infection control shield on the probing tip, calibration of the device was performed.

Then the mode of shade selection was chosen:

Tooth area measurement (Base shade determination), natural teeth mode. The target tooth was measured by positioning the tip at 90 degrees on the center of the middle 1/3 of labial surface for the exact hue and block shade (Figure 4 and 5).

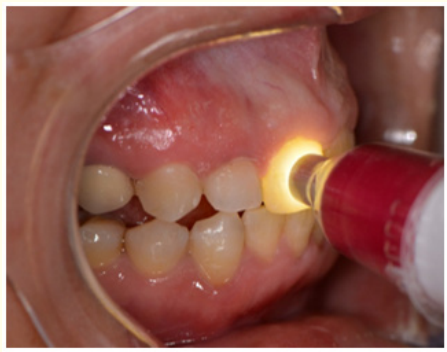

Figure 4: Shade selection.

*IvoclarVivadent Gmbh, Burs, Austria

**Flexipalette Color Match, Smile line, Switzerland.

* VITA, Zahnfabrik, Germany.

Figure 5: Easyshade V Base shade mode tooth measurement

A 3 spot mode shade mapping was also measured on the (cervical, middle, and incisal 1/3) for overall tooth color (Figure 6). Tooth was illuminated with spectrophotometer light, and the reflected light was analyzed. The display presented the closest shade selected in the classical and 3D Vita shade guide. The measurement was accepted when five successive, similar readings were recorded for each area. Only green (good) matching results were used [18].

Figure 6: Easyshade V 3 spot shade mapping.

In the third group, the shade was selected with digital photography (D). It was carried out within a standardized environment. A Canon 650D (DSLR) camera was used [6] with a 100 mm Canon macro lens and lens-mounted Yongnuo macro twin flash. The camera was mounted on a tripod with 70 cm fixed distance between the lens and the tooth [19]. The patient's head was stabilized with a head stabilizer, and a cheek retractor was placed (Figure 7).

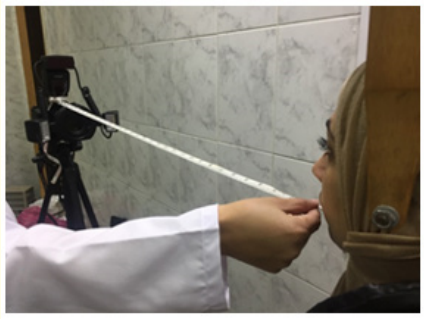

Figure 7: Fixed distance between lens and tooth.

Camera settings

The camera was set on manual mode with shutter speed 1/250, ISO 200 and custom white balance mode. Aperture for extra-oral photos was set to f/8, and for intraoral photos f/22. The lens was set to manual focus. Images captured were saved in RAW file format [12] (Figure 8).

Figure 8: Camera setting.

Flash settings

Manual mode at 1/4 Flash output for all images except the polarized image.

A polarizer was placed on the twin flash and the lens to reduce the gleam on the teeth by 30%. This enhances visualization and color assessment. Flash settings: was 1:1 and f/32 [20] (Figure 9).

The shade guide and the gray card were present in the image when taking the shade of the tooth. The gray card was utilized for the exposure calibration in Adobe Camera Raw. A WhiBal gray card was used in this study [12,20]. The shade tab and the gray card

were placed parallel to each other and aligned vertically in the same plane as the natural tooth with the incisal edge resting on the cervical portion of the shade tab [12]. Two or three of the closest shade tabs that were chosen were photographed to be evaluated with Adobe Photoshop.

Figure 9: Polarizer placed on the twin flash.

Adobe photoshop steps

Images were opened into Photoshop (Figure 10). The White balanced tool was selected for the gray card reading of L: 73/74 a: 0 b: 0. if the gray card didn't read between 73/74 then the exposure was adjusted [12]. The L: reading of the selected shade tab was obtained by placing the white balance tool on the center of middle 1/3 [12]. On the left panel, "INFO" was selected after opening "Window" [12]. Average 5 by 5 image was chosen [12].

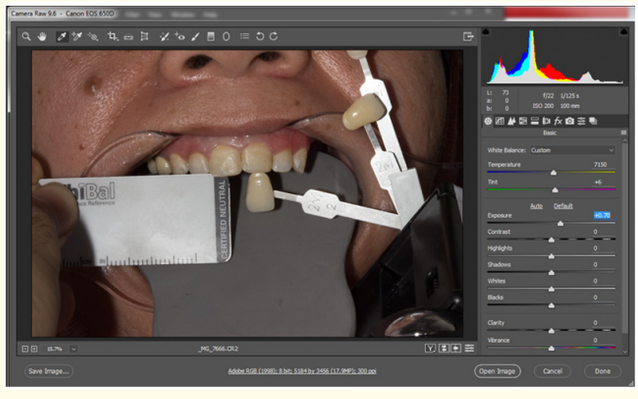

Figure 10: Adobe photoshop steps.

After clicking on that area with the mouse while the shift button remains pressed, the number or reading would appear on the Info panel.

The L a b color was selected from the Info window by using the small eyedropper tool [11] (Figure 11).

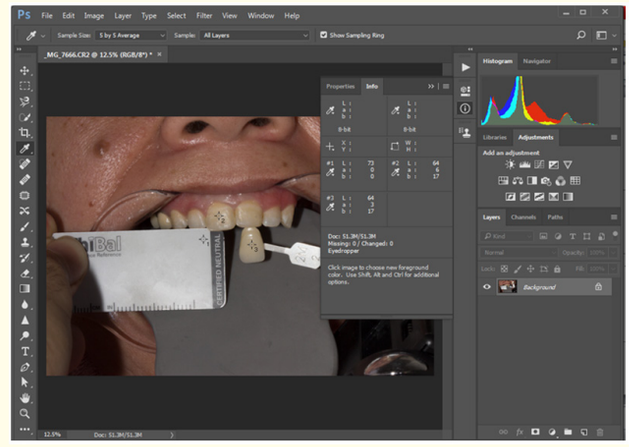

Figure 11: Reading of points in lab.

Click on the "HSB Color" option, which stands for hue, saturation, and brightness [12]. The shade was selected according to the Lab or HSB [12].

Conventional all-ceramic full coverage preparation was performed by preparing the tooth according to manufacturer's guidelines with supra-gingival chamfer finish line of 1 mm thickness, 2 mm incisal preparation with the labial surface prepared on two planes which was standardized by the use an index [21,22] (Figure 12 and 13).

Figure 12: Silicone index showing the amount of reduction labial and incisal.

Figure 13: Finishing and rounding of point and line angles of the preparation occlusal view.

The stump shade of the abutment tooth was selected visually using the Natural Die Material shade guide* under natural daylight and color corrected light [10,23] (Figure 14 and 15).

Figure 14: Tooth stump shade selection under natural day light.

Figure 15: Tooth stump shade selection using color corrected light.

The final impression was taken with addition silicone. Provisional restorations were fabricated and cemented with eugenol free temporary cement. All restorations were fabricated from IPS e.max CAD. After the designing and before the milling, the Ivoclar Vivadent application selected the block shade for the (V3D) group, (D) group while (VE) group was selected using the block feature in one point [24].

The tooth was polished prior to the esthetic try-in which was done under natural daylight and confirmed with color corrected light with the previously selected shade tab in (V3D) group. In (VE) group, the device was used for verification, while in the (D) group; the gray card was used to confirm the shade. After shade confirmation, staining and surface characterization were performed. Dual-cured translucent resin cement was used to cement the final restoration after the surface treatment was performed to the tooth and the restoration according to the manufacturer's instruction.

Data collection methods

Primary outcome

Patient satisfaction was evaluated using the binary Visual Analogue Scale (VAS) and recorded as satisfactory and unsatisfactory.

Participants were handed a mirror to inspect their teeth and evaluate the three restorations. The final crown was cemented based on the definitive selected restoration by the patient.

Secondary outcome

Five evaluators assessed in the shade matching of each group using the modified United States public health service (USPHS) criteria:

- **Alpha (Excellent):** Ideal.
- **Bravo (Acceptable):** Less than ideal but no modifications required
- **Charlie (Acceptable but needs modification):** Staining or other shade modifications.
- **Delta (Unacceptable):** Remake.

Shade matching after staining, glazing, and surface characterization was confirmed with the 3D master Shade tab, Vita Easyshade V spectrophotometer, and digital camera. Data were recorded, tabulated then statistically analyzed (Figure 16-18).

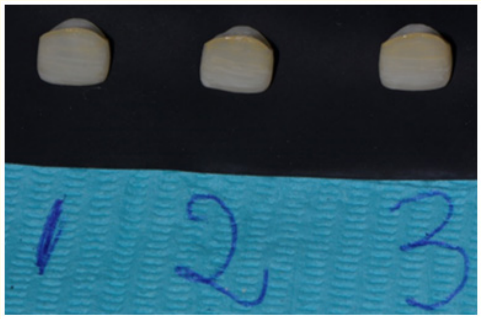

Figure 16: The three crowns placed on the bracket table for assessment.

*IPS Natural Die Material Guide, Ivoclar Vivadent.

Shade matching Evaluation Chart

Patient 1

Shade Matching Modified (USPHS) criteria	Ceramic Restoration 1	Ceramic Restoration 2	Ceramic Restoration 3
Alpha (A) Excellent : ideal			
Beta (B) Acceptable: less than ideal but no modifications required			
Charlie (C) Acceptable but modifications needed: staining or other shade modifications required.			
Delta (D) Remake			

Figure 17: Evaluation chart.

Figure 18: Evaluation of shade matching. (1) Visual shade tab group. (2) Easy shade V group. (3) Digital Camera group.

Results

Statistical analysis

Qualitative data were demonstrated as frequencies and percentages. The data obtained for evaluating the outcomes were statistically analyzed using Friedman's test and used to compare between the three groups. The significance level was determined to be at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp. Sample size (n = 9) was enough to detect large effect sizes for main effects and pairwise comparisons, and the satisfactory level of power set at 80% and a 95% confidence level [7].

Demographic data

This study was carried out on nine participants; all of them were females. The mean and standard deviation values for age were 30 years with a minimum of 20 and a maximum of 40.

Shade matching evaluation

The results of a comparison between the three groups were presented in table 1 and figure 19. There was a statistically significant difference between the three restoration types (*P*-value = 0.002, Effect size = 0.722). Six restorations of Group (V3D) showed (66.74%) Alpha score, while three restorations showed (33.3%) Bravo score.

All restorations of Group (D) showed a (100%) Alpha score. While for restorations of Group (VE): two restorations showed (22.2%) Alpha score, three restorations showed (33.3%) Bravo score, and four restorations showed (44.5%) Charlie score. All groups showed (0%) Delta score.

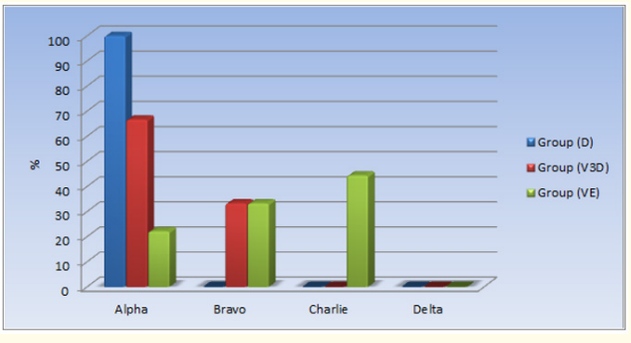

Figure 19: Bar chart representing shade matching scores.

Scores	Group (D) (n = 9)		Group (V3D) (n = 9)		Group (VE) (n = 9)		P-value	Effect size (w)
	N	%	N	%	N	%		
Alpha	9	100	6	66.7	2	22.2	0.002*	0.722
Bravo	0	0	3	33.3	3	33.3		
Charlie	0	0	0	0	4	44.5		
Delta	0	0	0	0	0	0		

Table 1: Frequencies (n), percentages (%) and results of Friedman's test for comparison between shade matching evaluation scores of the three groups.

*: Significant at P ≤ 0.05.

Patient satisfaction

The results of patient's satisfaction associated with restorations is highlighted in table 2 and figure 20.

All restorations of (D) group and (V3D) group restorations were (100%) satisfactory for the patients. Regarding the restorations of the group (VE), 55.6% were satisfactory, and 44.4% were not satisfactory. There was a statistically significant difference between the three groups (*P*-value = 0.018, Effect size = 0.444).

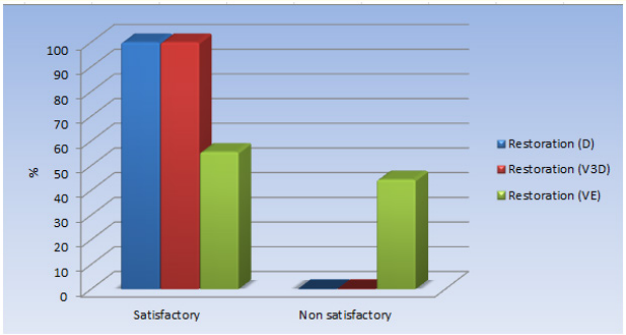

Figure 20: Bar chart representing patient satisfaction.

Satisfaction	Restoration (D) (n = 9)		Restoration (V3D) (n = 9)		Restoration (VE) (n = 9)		P-value	Effect size (w)
	N	%	N	%	N	%		
Satisfactory	9	100	9	100	5	55.6	0.018*	0.444
Unsatisfactory	0	0	0	0	4	44.4		

Table 2: Frequencies (n), percentages (%) and results of Friedman's test for comparison between satisfactions with the three restoration types.

*: Significant at P ≤ 0.05.

Discussion

In the present study, all teeth included were anterior teeth due to their presence in the esthetic zone as they are very challenging in terms of shade matching and patient satisfaction [5]. Starting by the visual shade matching, Vitapan 3D-Master shade guide was chosen in this study due to its extensive use in dental clinics. Also, the recommendation of several studies about the shade tabs' color being evenly distributed, enables accurate shade matching with the natural teeth. Li., *et al*. [25] and Zenthöfer., *et al*. [26], who assessed the commercial shade guides, reported that the Vitapan 3D-Master shade guide was efficient and facilitated the shade selection in the clinic because the shade tabs were more evenly spaced in the color spectrum.

Illumination also plays a significant role in producing an accurate shade selection; therefore, a color corrected light was used with 5500K color temperature as an adjunctive tool for optimum shade selection. Illumination in the dental office is a mixture of daylight and light generated by the dental chair lamp. Since these conditions are incredibly variable, light correcting sources have been recommended to be used during shade selection in dentistry [27]. According to Curd., *et al*. [28], dental students provided better shade matching outcomes using a color corrected light than natural light. Also, Joiner [29] and Clary., *et al*. [15] found that shade matching results with handheld lights were superior to those acquired with a viewing booth or natural daylight.

Earlier, Fondriest J [16] stated that most humans have eye dominance, and thus, it was not recommended to place the shade guide on the side of the tooth; otherwise, one eye would preferentially perceive the shade, giving inaccurate evaluation. He also reported that shade tabs should be positioned in the same plane of the tooth, neither in front of it as it would appear lighter, nor behind it as it would appear darker. Pitel ML [30], suggested placement of the shade tab below the tooth, with the incisal edge towards the tooth's incisal edge, which was considered more favorable for reflection of the light perceived by the eye. The best background for hue and chroma selection is gray because neutral gray has no complementary color, making it restful to the retinal cones [16].

Moreover, McLaren., *et al*. [12] stated that to control the shade selection environment, the teeth needed to stay hydrated, as de-

hydration causes the teeth to appear brighter. Using cheek retractors causes the saliva to dry quickly; thus, a medium-viscosity clear glaze liquid was used to wet the teeth and shade guide. This procedure was performed in both groups (V3D) and group (D) during shade selection.

In the present study, trained and experienced prosthodontists were chosen for color evaluation. According to Jaju., *et al*. [31] and Ristic., *et al*. [32] clinical experience and knowledge of color science could enhance the performance clinically in complex color matching.

3 females and 2 males prosthodontist evaluators were selected in this study, there was no significant gender influence on shade matching ability as Clary., *et al*. [15] and Joshi and Acharya J [33] found.

Because the consistency and reliability of visual shade matching were questioned, Vita Easyshade V was used in this study, according to Kim-Pusateri., *et al* [17]. Several brands were tested against many different types of shade guides, in simulated conditions, multiple times. Reliability results were similar; all the tested instruments scored in the 90% range. Accuracy, however, showed statistically significant differences ranging from 60% - 90%. Only the Vita Easy Shade scored within the 90% range for both accuracy and reliability.

After performing a systematic review of visual and instrumental measurements for tooth shade matching, Chen., *et al*. [34] found that the instrumental method provided the most precise and accurate shade-matching outcomes. Moreover, to improve the esthetic outcome, Igiel., *et al*. [35] suggested using color matching instruments as supplementary tools in daily dental practice.

In recent studies, digital photography plays an increasingly important role in everyday dental practice as a useful communication tool between the dentist and the laboratory. Several (DSLR) cameras are available in the market where the most commonly used camera brands in dental photography were Canon at 48% with a macro lens of a 100 mm and Nikon at 52% with a macro lens of 105 mm [16].

A Canon DSLR camera was used in this study. The settings were in accordance with Culic., *et al*. [36] that had the images standardized by adjusting the dental camera settings as follows: manual mode 'M' which allowed the manual control of exposure's parameters, F22 aperture value, and 1/200 Shutter speed, manual focus, maintaining a constant distance between the lens and the object; white balance – flash (color temperature 6500K); ISO 100 and flash mode manual at ¼ power ratio. In another study, Oh., *et al*. [37], used the Nikon D70s DSLR camera set on manual mode (M) program, with a 105 mm macro lens at 1:1 magnification. The shutter speed was set at 1/125 seconds with the aperture of F/20. At an angle of 45 degrees, a bilateral flash was fixed to the front of the camera lens. For standardization purposes, a fixed distance between the teeth and the camera was set before taking an image. Unfixed camera distance was considered as uncontrolled environmental factors. In this experiment, the shooting distance was set to 70 cm in accordance to Miyajiwala's., *et al*. study [19].

Earlier in 2009, Ahmed., *et al*. [38] reported that the light output of electronic flashes was corrected to 'photographic daylight' with a color temperature of 5,500 K. Photographic daylight, instead of natural daylight, is the ideal light for photography, automatically adjusted by the camera unlike natural daylight which may change according to external uncontrolled conditions. Natural daylight produced a continuous, seamless spectrum while electronic flash produces a discontinuous spectrum. Therefore, in this study, the light of the twin flash was considered sufficient to ensure ideal conditions for shade selection and the use of an external color corrected light was not necessary.

Also, McLaren and Chang [39] compared different camera flashes and reported that the ring flash tends to flood the scene with light, giving a flat image. The surface texture and translucency couldn't be captured with this type of flash. A dual-flash can record surface texture detail and contour and is best used for anterior teeth.

McLaren., *et al*. [12] used a DSLR camera, a macro lens and a twin flash suitable for macro photography tethered into Adobe Photoshop CC using the RAW format.

According to the manufacturer and Liu, 2019, the YN-24EX twin flash was a great alternative to the highly priced Canon MT-24EX macro twin flash [40].

In accordance with Hein and Zangl [20] and McLaren., *et al*. [12], the use of a standardized gray reference card promised to overcome the limitation of visually perceivable effects in the digital images through a remapping process of the original RAW image to a defined standard.

They have also found the most accurate card to be the WhiBal® card, which had an L value between 74 and 75 as measured in the CIELAB. Determining the value sometimes could be challenging. A polarized light filter would eliminate the reflected light making it easier to define wither the brightness is caused by low chroma or high surface reflectivity. In other words, the cross-polarized filters eliminate specular reflections that conceals the fine details of the tooth, providing a glare-free image. A polarized image improved the visualization of the dentin base shade and fine enamel features, providing a chromatic map [16].

Hein and Zangl [20] and McLaren., *et al*. [12] analyzed the shade using a polarized filter sheet for cross-polarization, which revealed intrinsic shade variations of natural teeth.

Shade matching results revealed that the digital camera and visual method outcomes were comparable. The only difference was in the surface characterization as in the (D) group in which sending a photograph to the laboratory made the restoration look identical to the tooth in comparison to shade map drawing in (V3D) group where some details may be missed which had a direct impact on the results.

The Alpha score results obtained might be reasonable since it is the combined reflection of the meticulous shade matching protocol. The performance of (VE) group in cases of monochromatic teeth was accurate and reliable, while in 4 restorations that had surface characterization and surface texture, the final outcome was affected.

In agreement with Anand., *et al*. [41], this study revealed that digital photography was as accurate as the most commonly used method for shade selection and that a DSLR camera with Adobe Photoshop could be a replacement to a spectrophotometer in acquiring 'L' and 'b' values precisely.

Schropp [42] reported no statistical differences between visual and digital measurements. In contrast, Jarad., *et al*. [43] reported that the observers' shade matching performance was significantly higher with the computer method compared to the conventional one, and also stated that digital imaging reveals more information related to the tooth color, shape, and particular characteristics that the technician may use to fabricate an ideal restoration.

McLaren., *et al*. [12] reported difficulty in describing a complex, multi-layered, multi-textured, 3D color scheme with a 2D shade guide system. A precise clinical photograph could register various details that would be un-noticeable by the eyes.

Hein., *et al*. [44] stated that the shade matching performance of the observer was remarkably improved with the computer method using the digital camera with a significant variability in the observer's matching capability when selected visually.

Coinciding with the results in this present study, Kim [18] stated that while two dissimilar EasyShade V devices showed high repeatability of CIE L^*, a^* and b^* measurements, they provided inconsistent color values and shade for the individual tooth caused by tooth curvature along with the concise aperture size which leads to edge loss effect. The translucency and surface characteristics could influence the repeatability and accuracy of the EasyShade V. Additionally, it wasn't often convenient to place the aperture on the same area each time.

Contradicting results according to a systematic review, Chen., *et al*. [34] reported that nine out of seventeen studies showed more precise outcomes using a spectrophotometer. While, three studies showed relatively lower reproducibility, caused by device-dependent biases. Regarding the eight studies inspecting the shade matching accuracy, three studies reported higher accuracy rates. In some studies, the spectrophotometer is considered a gold standard for shade selection.

This was explained by Kim [18], who reported that shade matching accuracy, using spectrophotometer devices, in the in vitro studies were higher than in vivo.

Zeighama., *et al*. [45] pointed out several factors affecting the final color of the restorations including porcelain layering technique [46], dental ceramic type, primary shade [47], ceramic brand [48], thickness of veneering ceramic [49] and firing cycles [50,51]. Additionally, the cement type, color and thickness also contributed to the final color.

Regarding lithium disilicate CAD crowns, Fasbinder., *et al*. [52] reported that Alpha scores were recorded even after two years.

Moreover, Rauch., *et al*. [53] found that the color of all lithium disilicate crowns recorded only Alpha scores after 6 and 10 years.

Patient satisfaction

The 100% patient satisfaction of both (D) and (V3D) group could be justified by the sensitivity of dentists towards the identification of the deviations in the shade than laypeople. While in (E) group, only 5 patients were satisfied, and 4 patients were not satisfied because these restorations were, according to the patients, more yellowish. It was coinciding with the results of shade matching recorded previously by the 5 evaluators.

In 2017, Ballard., *et al*. [54] added that participants reported high satisfaction which was influenced by the lightness of the crown's shade.

In contradiction to our results, Shah., *et al*. concluded that the general patient satisfaction was moderate [55]. They clarified that the level of education of the patients had an effect on the results.

Also, Ballard [54] reported that dental school patients were aware that students were performing the restorations. This could slightly lower their expectation for the restorations' shade compared to an analogous private practice patient.

Finally, the hypothesis was rejected as digital photography group was graded Alpha. It was found to be an accurate method that can be used with the visual method or as an alternative for spectrophotometer in shade matching.

The limitations of this study were:

- Further clinical studies on larger sample size with the use of different softwares available in the market are recommended.
- A practitioner, with inadequate knowledge of Adobe Photoshop can encounter difficulties in shade selection.
- Patients with severely discolored teeth and different processing techniques as layering or cut-back may affect the final outcome.

Conclusion

- Digital photography method proved accuracy in terms of shade selection and surface characterization over the conventional visual method.
- Spectrophotometer, as an objective method, showed inability to capture the various tooth surface characterization and recorded excellent results in case of monochromatic teeth.

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