Original Article

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Dentistry Section

Comparative Evaluation of Colour Difference using Different Digital Photography Equipment to Standardise Colour Assessment in Dental Photography

JAIMINI JIGAR PATEL[1], NIMISHA CHINMAY SHAH[2], RUCHI RANI SHAH[3], MEGHNA KOTHARI[4], PRIYA PORWAL[5], RENU BATRA[6]

ABSTRACT

Introduction: Photography has always been thought to be an important part of dentistry. Since the introduction of digital technology; imaging has become simpler and more accessible. Colour matching is critical for the success of restorative and prosthetic dental treatments, also communication with the dental laboratory is still subjective, and further research is needed on this aspect.

Aim: To compare the colour difference using different digital photography equipments to standardise colour assessment in dental photography.

Materials and Methods: A single blind clinical study was conducted on total 22 participants from December 2020 to June 2021. A spectrophotometer was used to determine the Colour space defined by International Commission on Illumination (CIELAB) values of the right central incisor for each participant. They were then photographed with five different photography equipment along with a grey reference card. The five different groups were: Group A: Canon 1300D Digital Single Lens Reflex (DSLR) with 100 mm lens and pop-up flash (N=22). Group B: Canon 1300D DSLR+100 mm lens+70 GSM white tissue paper (N=22). Group C: Canon 1300D DSLR+100 mm lens with ring flash (N=22). Group D: Canon 1300D DSLR+100 mm lens+ring flash+diffuser (N=22). Group E: Iphone 11 (N=22). CIELAB values were obtained for all the groups using adobe Photoshop software after white balancing. Delta E was calculated by comparing CIELAB values of each group with the spectrophotometer values. The data was tabulated and analysed with one way Analysis of Variance (ANOVA) and Posthoc test using IBM Statistical Package for the Social Science (SPSS) version 20.0 software with p-value <0.05 considered statistically significant.

Results: Mean value of Delta E was least in group D (DSLR+ ring flash with diffuser) (5.033) followed by group B (DSLR+ pop up flash with white tissue paper) (6.57), group A (DSLR+pop-up flash) (10.70), group E (Iphone11) (10.74) and highest in group C (DSLR+ ring flash) (11.32).

Conclusion: Group D (DSLR+ring flash with diffuser) was determined to be closest to the standard spectrophotometric values for colour assessment in dental photography.

Keywords: Adobe photoshop software, Colour assessment, Delta E, Spectrophotometer

INTRODUCTION

Dentistry can either be a profession of immense satisfaction or a routine treadmill. One way to enhance patient satisfaction is to utilise dental photography in day-to-day practice. Digital dental photography's primary purpose is to precisely capture the clinical findings of the oral cavity, but it can also be utilised for treatment planning, legal documentation, analysis of smile width and buccal corridor during smile designing, accurate colour rendition, and communication with laboratory workers or patients. The practice of photography is exciting for both patients and clinicians, generating passion for routine practice [1].

In contemporary dentistry, there are various factors that influence the shade of any restoration, including textures, dentist's judgement, and patient characteristics [2]. It is a subjective assessment that changes from person to person [3].

Shade matching in dentistry can be performed visually, with instruments, or by a combination of two. Visual selection alone is subjective and strongly dependent on the interaction between light and therefore the dental structure, with the ultimate decision depending on the operator. When it comes to shade matching with instrument, the most used ones include a spectrophotometer, a spectroradiometer, a colourimeter and a digital camera. This instrumental analysis is advantageous because it enables dentists to perform an objective analysis that is more accurate and reproducible [4]. These devices, however, lack inter-device reliability and require specific, expensive technology that is not always available to clinicians. Digital cameras are a standard communication tool in dental offices and may be used for electronic shade registration. Though mobile photography has acquired a lot of popularity recently because of its user-friendliness and compact design, there are still areas where it falls short of a DSLR system, with downsides such as smaller sensor size and increased image distortion [5,6].

Extraoral and intraoral dental photography necessitates a few additional devices in addition to the DSLR, such as a macro lens, ring flashes or twin flashes, bouncers, and diffusers to improve colour information [7]. Macro lens systems have a larger diaphragm and a higher magnification than other armature lenses. They allow for a sharper focus in close-up pictures. Medical and technician offices mainly benefit from macro lens of 100 mm focal length, so that the pictures can be taken at their original magnification [7].

Ring-flashes generate a uniform blast of light that is suitable for photographing posterior teeth or hard-to-reach areas, but are not recommended for photographing anterior teeth due to the harsh explosion of light. This necessitates the use of a twin flash, which can more effectively record the minute characteristics of anterior teeth. On the other hand, a dual flash or twin flash is far more expensive than a ring flash, and the shortcomings of ring flash can be overcome by using a diffuser [8].

Flash diffusers are light enhancers that attach to the upper edge of external flash units. Its purpose is to tone down or disperse the harsh intense light that bursts out from the flash, resulting in a more uniform and natural looking light on the subject [9]. Commercially available professional diffusers can be quite expensive and range from 10-100$. In such cases, a white tissue paper of 30-70 Gram per square metre (GSM) thickness, scratch tape, white printing paper, polyethylene (PET) or any semi-opaque material that safely covers the flash can be used on top of the pop-up flash as a diffuser for cross polarisation simultaneously cutting down the cost of an extra accessory [10].

Cameras have a white balance setting that controls how the colours are captured under different types of lighting. The temperature of colour varies from cool (blue tint) to warm (orange tint). By setting the white balance correctly; we can eliminate unwanted colour casts in an image and make it look natural [11]. Therefore, digital dental photography should be recorded with a grey card of known colour coordinates for better accuracy [12].

Since, there is a scarcity of information on the usage of various digital photographic equipment and accessories like ring flash and cost-effective diffusers for shade evaluation using a digital technique, this study focuses on comparing all the different less expensive combinations of digital imaging for getting the most accurate colour assessment. Therefore, the study was carried out with the aim of comparing the colour differences using different digital photography equipment to standardise colour assessment in dental photography.

The null hypothesis tested was there is no colour difference by using different digital photography equipment used to standardise colour assessment in dental photography.

MATERIALS AND METHODS

A single blind clinical study was conducted in the Department of Conservative Dentistry and Endodontics, KM Shah Dental College and Hospital, Vadodara, Gujarat, India for a period of six months from December 2020 to June 2021. The clinical protocol and informed consent was approved by Institutional Ethics Committee (SVIEC/ON/DENT/SAP/20137) and protocol was registered with CTRI (CTRI/2021/02/031302).

Inclusion and Exclusion criteria: Patients between the age of 16 to 45 years, who are ready to give consent and having Angle's Class I occlusion were included in the study. Those patients with anterior tooth restoration, history of bleaching in last six months hypoplastic/ discoloured teeth, with congenital abnormalities, dental caries, poor oral hygiene and periodontitis were excluded from the study.

Sample size calculation: Minimum sample size required were 22 patients with 95% Confidence Interval (CI) and 80% power using this formula: $N=(Z_1+Z_2)^2 * SD^2/d^2+1.921$. Each patient was evaluated with five different dental photographic Groups (22×5=110 photographs). Hence, total sample size was 110 [10].

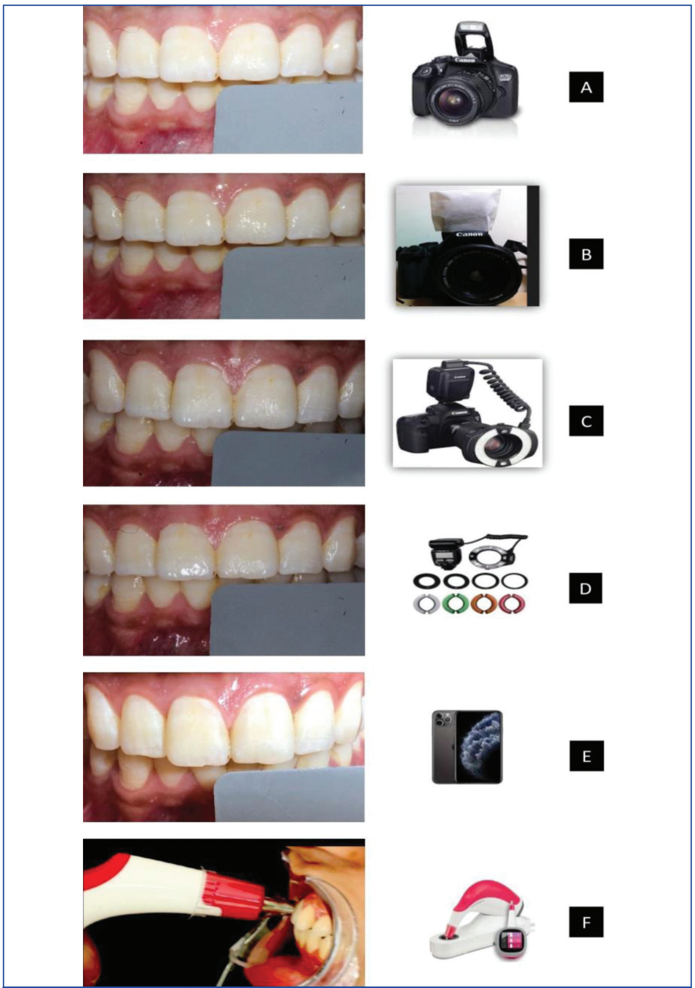
Study Procedure

Spectrophotometric evaluation [Table/Fig-1a-f]:

CIELAB values were recorded from the center of the right maxillary central incisor of each patient with a Vita easy shade advance spectrophotometer (VITA Easy shade Advance; Vident, Brea, CA, USA, Lot: H25543). The obtained values were considered as gold standard and compared with five experimental groups. The five different groups were:

- Group A: Canon 1300D DSLR (CanonInc., Japan)+100 mm lens with pop-up flash (N=22) [Table/Fig-1a]
- Group B: Canon 1300D DSLR+100 mm lens with pop-up flash +70 GSM white tissue paper (N=22) [Table/Fig-1b].
- Group C: Canon 1300D DSLR+a 100 mm lens with a ring flash (Yongnuo flash system, China) (N=22) [Table/Fig-1c].
- Group D: Canon 1300D DSLR+100 mm lens with a ring flash+diffuser (N=22) [Table/Fig-1d].
- Group E: Iphone 11(N=22) [Table/Fig-1e].

Thus, the total photographic evaluation done was 110.



[Table/Fig-1]: Group A: DSLR +Macro lens+ Pop up flash, Group B: Tissue paper, Group C: Ring flash, Group D: Ring flash+diffuser, Group E: Iphone 11, Group F: Control- Spectrophotometer Group).
(Declaration: All the pictures have been taken by the author in Department of Conservative Dentistry and Endodontics, KM Shah Dental College and Hospital)

The following standardised calibrated DSLR parameters were used for the photographic evaluation: Shutter Speed-1/125, Aperture/focal-spot-25, ISO-200, flash-manual, Distance-30 cm, and magnification ratio-1:3 [10]. Dual 12MP ultra-wide cameras, f/1.8 aperture, digital zoom upto 5x for Iphone 11. Participants were instructed to keep their mouth closed with the maximum intercuspal position; sit upright with a stable head position to make sure that the occlusal plane of maxillary teeth is parallel to the floor. To permit consistent flash intensity, photographs were taken at 1-minute intervals, and patients were asked to close their mouths between photographs to avoid tooth dehydration. These photographs were taken between 9 am to 12 noon in northern daylight. A standard grey reference card with known colour values (L*=75, a*=0, b*=0) was kept near the mandibular anterior teeth for white balance analysis for all photographs.

Digital assessment: In order to determine Delta E, colour accuracy (total colour difference) is calculated by combining delta L*, delta a*, and delta b* values. These values provide a graphical representation of colour in rectangular coordinates. Delta E values between 3 and 6 are generally considered acceptable in commercial reproduction [10].

Using Light room software (v 6.0, Adobe Photoshop CC; Adobe Systems Inc) CIELAB values were taken from each photograph by clicking on the center of the tooth. Obtained data within each group was compared with the spectrophotometer readings to derive Delta E for each group. The Delta E between these CIELAB coordinates was calculated using a formula as given in CIE prescriptions:

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

The L, a, b values obtained with spectrophotometer were used as L_1, a_1, b_1 with each experimental group to calculate delta E (i.e., the colour difference between spectrophotometer and experimental group). Blinded evaluator was a trained professional in dental photography and Adobe Photoshop software and was practising the same from 5-6 years. Observer bias was eliminated by selecting a midpoint of the tooth for evaluation of the photographs.

STATISTICAL ANALYSIS

The data was tabulated and analysed with one-way ANOVA and posthoc test using IBM Statistical Package for Social Sciences (SPSS) 20.0 (IBM SPSS Inc, Chicago, IL USA). For all statistical analyses, probability levels of p-value <0.05 were considered as statistically significant.

RESULTS

Among the 22 patients, 6 (27.27%) of the patients were men and 16 were women (72.72%). Total 15 patients (68.18%) were between age group 16 to 30 years, while the remaining 7 patients (31.81%) ranged in age from 31 to 45 years. [Table/Fig-2] shows the one-way ANOVA analysis of mean Delta E values of all the experimental and control groups. From the obtained result Delta E value for each group are as follows, group C (DSLR+ring flash) (11.32), group E (Iphone) (10.74), group A (DSLR+pop-up flash) (10.70), group B (DSLR+pop up flash with white tissue paper) (6.57), group D (Canon 1300D DSLR+100-mm lens with a ring flash+diffuser) (5.033) was lowest among all groups.

Groups	N	Mean	Std. Deviation	Statistic/f	p-value
Group A	22	10.706136	4.027336	16.718	<0.001
Group B	22	6.570909	1.6761262		
Group C	22	11.329091	5.5108118		
Group D	22	5.033182	1.6628902		
Group E	22	10.742727	5.857348		
Total	110	8.876409	4.8276887		

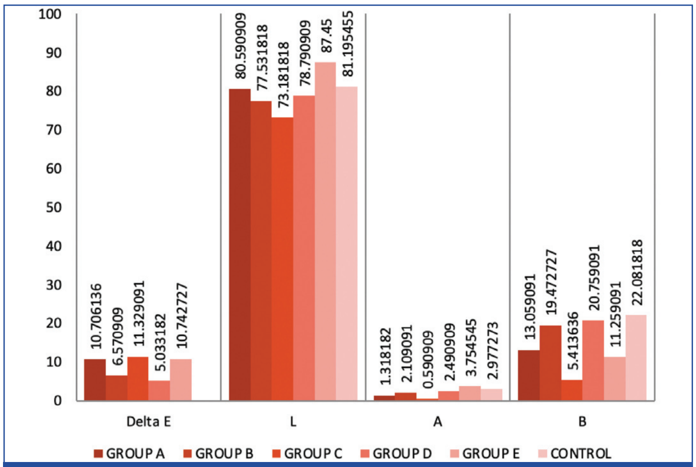
[Table/Fig-2]: Mean delta E values with one-way ANOVA analysis.
p-value <0.05 considered significant

[Table/Fig-3] shows the intergroup comparison of Delta E using posthoc test. Group A was having statistically significant difference with group D (p<0.001), group B with group C and E, (p=0.0020 and 0.0100), respectively, group C with group D (p<0.001) and group D with group E (p<0.001). However, there was no statistically significant difference observed between group A with B and C (p=0.753 and p=0.988).

[Table/Fig-4] shows the Delta E and L* a* b* values among group A, B, C, D, E and control group (spectrophotometer) which states that group D (Canon 1300D DSLR+100-mm lens with a ring flash+diffuser) (ΔE=5.033) was closest to the standard values. Delta E values range between 0 to 100 and values closest to 0 have the most accurate colour matching which was group D according to this study.

Comparison of	Comparison with	Mean difference	Standard error	p-value
Group A	Group B	4.1352273	1.253878	0.7530
	Group C	-0.62295	1.253878	0.9880
	Group D	5.6729545*	1.253878	<0.001
	Group E	-0.03659	1.253878	1.0000
Group B	Group C	-4.7581818*	1.253878	0.0020
	Group D	1.537727	1.253878	0.7360
	Group E	-4.1718182*	1.253878	0.0100
Group C	Group D	6.2959091*	1.253878	<0.001
	Group E	0.586364	1.253878	0.9900
Group D	Group E	-5.7095455*	1.253878	<0.001

[Table/Fig-3]: Intergroup comparison of delta E with posthoc analysis.
*p-value <0.05 considered significant



[Table/Fig-4]: Comparison of delta E values and L* a* b* values among all the groups.
L* for perpetual lightness; a* and b* for four unique colours of human vision: red, green, blue and yellow

DISCUSSION

Dental professionals have long sought to achieve the incredibly desirable but difficult goals of dental shade evaluation, proper colour communication, and most importantly reproducing natural tooth colour in a final restoration that matches the adjoining tooth structure. It is often hampered by several variables [13-16]. Colour perception is most affected by the type of lighting present. Even the best lighting and viewing setups for doing visual shade analysis are not universally acknowledged. Additional obstacles include the variability of commercially available shade systems, individual human disparities in colour perception, and a lack of awareness of colour science, especially as it pertains to tooth shade. The highly complex nature of colour distribution within a tooth and how form, surface texture, and gloss affect perception of colours further complicate these challenges [17].

Based on the results of this study, the null hypothesis was rejected, the group D with the digital camera with a 100-mm lens+ring flash+diffuser showed an acceptable Delta E value. The findings of this study are in agreement with two other studies by Sampaio CS et al., and Sirintawat N et al., who found that using a DSLR with a ring flash alone produced the least accurate results, while using a DSLR with a ring flash+diffuser or cross polarising filter produced results that were more accurate and comparable to using a DSLR with twin flash [10,18]. The results obtained from this study are in contrast with the results obtained of a study conducted by Bhat VS et al., who evaluated the colour accuracy of tooth shade captured with more recent smartphones and DSLR cameras and found no significant difference between the two [19]. However, the smartphones used in the study are of upgraded version which explains the good photographic quality. The most modern high-resolution smartphone cameras have manually adjustable parameters, making them similar to DSLR cameras.

The results of this study are similar to the findings of study conducted by Hein S and Zangl M where they studied standardised gray reference card with five diffusers concluded that cross polarising filter as a diffuser plays a significant role in dental photography [12]. Macro lenses with a fixed 85-105 mm focal lengths are frequently used to aid in better focus and provide sharper images [20,21].

A number of electronic shade matching tools, like spectrophotometers and colourimeters, have also surfaced in recent years and are assisting us in choosing the ideal hue [6]. The most precise, practical, and adaptable tools for colour matching and surface colour measurement, according to Paul S et al., are spectrophotometers [22]. The spectral reflectance or transmittance curves of specimens are measured by spectrophotometers. As a result, the gold standard in this study was decided to be a spectrophotometer [23-25]. The precise positioning of the mouthpiece provides accurate measurements in the form of L* a* b* values and an easy-to-use colour analysis system. Because the spectrophotometer was unable to capture an image of the tooth, it became necessary to incorporate a digital photograph of the tooth into the colour selection technique.

Designers, web professionals, video editors, and photographers worldwide utilise Adobe Photoshop CC to work with high quality digital photos. Using this quick, inexpensive digital software, a dental technician can alter the photos and spot more detail. However, it is ineffective when done with a mobile device. Ambient light can have an impact on mobile photography with limitations such as increased image noise and distortion, reduced sensor size, and fixed lenses [10].

Professionals used a DSLR camera with recommended settings, a ring flash, and diffusers to capture high-quality photographs of teeth and determine exact shade measures. Digital photography can be a helpful tool for the laboratory technician and dentist to quantify shade, but it is not sufficient on its own to do so. The ideal lighting, settings, tools, and advanced technologies are necessary for picture communication. The package comes with a camera body, a suitable lens, and a flash setup [12].

The findings of this study support the results obtained by Saincher R et al., [26]. They carried out a pilot study to evaluate the image quality and colour accuracy of three dental photography cameras: point-and-shoot, DSLR, and mobile phone. They arrived to the conclusion that quality of point, shoot and DSLR cameras is equally good and better than mobile cameras, which produce brighter and more yellowish image.

Diffusers used in the present study were white tissue paper with 70 gsm and commercially available diffusers for a ring flash. Placing such diffusers of varying opacities in front of the light source can reduce the output and soften the emitted light, creating a more even and flattering light on the subject. Additionally, it helps eliminate shadows that are caused by harsh lighting [27].

Various electronic flash systems are available in the market. These electronic flashes help to capture the highly reflective enamel surface and also the layer beneath it. The ring-flash technique was utilised in this investigation as it produces a consistent burst of light, which is ideal for photographing posterior teeth or difficult-to-reach locations. On the other hand, twin flashes create shadows and highlights around the teeth to make them appear more three-dimensional, with increased contrast and detail. However, it is an expensive affair and difficult to focus on posterior teeth [28].

A distinct spectrum of light and dark regions, including white teeth, pink soft tissues, and a dark oral cavity background, can be found in the oral cavity. By balancing the various red and yellow tone proportions, white balance enables proper communication. Calibration with an 18% grey card is the most precise way to adjust the white balance. The teeth are photographed next to a neutral density grey card with the right placement of the card and the lighting configuration. In Adobe® PhotoShop, this obtained image is used as a reference.

Although the averages of a* and b* showed higher similarity, which can also aid with colour matching acceptability, the L* value, which corresponds to brightness, is the most studied. The Delta E value will typically range from 0 to 100 on a scale. The Delta E value range between 1 to 10 is more visible to the naked eye. Hence, Delta E was evaluated in the present study [29].

Hein S et al., presented a case study on the use of a newly designed workflow for objective shade communications and visual shade evaluation, as well as the usage of shade guidance. By combining numeric shade measurement with dental photography, he concluded that the e-LAB method allows for objective shade communication [30]. In dentistry, the e-LAB system offers a feasible alternative to the traditional approach of shade communication and matching.

Limitation(s)

The limitation of the present study include a small sample size and a limited number of digital imaging combinations such as DSLR with ring flash, or twin flash, mounted or DIY diffusers, spectrophotometer, shade guide. More research is needed in future on various digital imaging combinations and with the use of newer digital photographic equipments like mirrorless cameras, smile lite Mobile Dental Photography (MDP) and newer smartphone cameras.

CONCLUSION(S)

Within the limitations of this clinical study, it was concluded that the combination of DSLR+100 mm lens with ring flash+diffuser was the most accurate for digital photo acquisition because it showed the lowest Delta E. It should be recommended for shade communication to the laboratory. DSLR+100 mm lens with ring flash and Iphone showed higher ΔE value hence not advised to use in day-to-day practice. Diffusers are advised in digital photography to soften the harsh image. The grey reference card promotes digital imaging standards and aids in laboratory communication.

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PARTICULARS OF CONTRIBUTORS:

1. Postgraduate Student, Department of Conservative and Endodontics, KM Shah Dental College and Hospital, Sumandeep Vidyapeeth, Pipariya Waghodiya, Vadodara, Gujarat, India.
2. Professor and Head, Department of Conservative and Endodontics, KM Shah Dental College and Hospital, Sumandeep Vidyapeeth, Pipariya Waghodiya, Vadodara, Gujarat, India.
3. Professor, Department of Conservative and Endodontics, College of Dental Sciences, Bhavnagar, Vadodara, Gujarat, India.
4. Postgraduate Student, Department of Conservative and Endodontics, KM Shah Dental College and Hospital, Sumandeep Vidyapeeth, Pipariya Waghodiya, Vadodara, Gujarat, India.
5. Postgraduate Student, Department of Conservative and Endodontics, KM Shah Dental College and Hospital, Sumandeep Vidyapeeth, Pipariya Waghodiya, Vadodara, Gujarat, India.
6. Professor, Department of Conservative and Endodontics, KM Shah Dental College and Hospital, Sumandeep Vidyapeeth, Pipariya Waghodiya, Vadodara, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Nimisha Chinmay Shah,
Professor and Head, Department of Conservative and Endodontics, KM Shah Dental College and Hospital, Sumandeep Vidyapeeth, Pipariya Waghodiya,
Vadodara, Gujarat, India.
E-mail: nshah7873@gmail.com

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