VOLUME-7, ISSUE-10, OCTOBER-2018 • PRINT ISSN No 2277 - 8160

Original Research Paper

Dental Science

COLOUR ACCURACY OF COMMERCIAL SLR, DIGITAL AND PHONE CAMERAS FOR ASSISTED SHADE SELECTION – A DIGITAL PHOTOGRAPHIC AND SPECTROPHOTOMETER COMPARATIVE STUDY

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ABSTRACT A total of 126 dental students comprising of both males and females were randomly selected as the study subjects. A standardized photographic procedure is used to obtain images of maxillary central incisor using DSLR, Digital point and shoot and mobile phone cameras. A grid was used to divide the maxillary central incisor into 9 segments. The middle segments of cervical, middle and incisal parts of maxillary central incisor tooth were taken as colour patches and CIE LAB values were measured with a spectrophotometer, was taken as a control. Similarly CIE LAB values of shade tabs obtained from the spectrophotometer and digital image samples. Then the magnitude of colour difference between the parameters of spectrophotometer vs digital images of central incisor and shade tabs were calculated (ΔE) and are correlated. A one way ANOVA analysis was performed showing statistical significance in the incisal third of the central incisal and digital camera being the one which is showing highest mean value among the three cameras.

KEYWORDS : shade tab, spectrophotometer, digital images, digital cameras

INTRODUCTION

Esthetic demands in today's world of dentistry are scaling new heights, and are driven just to look beautiful. Shade matching is the important step in fabrication of restoration or prosthesis. To have a life like effect, shade of the target tooth should be accurately matched and then accordingly communicated to laboratory technician. There are two ways of prescribing colour, one is through the use of shade guides and other through the use of shade matching instruments which comprises of spectrophotometer, colorimeter, and digital camera along with imaging systems[1,2]

Accurate shade matching is one of the most challenging aspects of dental restorations and aesthetic dentistry. Due to the great variety of natural tooth colour, achieving a close shade match of an artificial restoration with the natural dentition is a complex process. Practitioners require an understanding of colour, light and related characteristics of porcelain and resin, as well as the ability to clearly communicate instructions with laboratory technicians.

Since Newton`s experiments during the 18th century, colour and science have tried to find a common field. But colour is difficult to manage, as it is usually something that has been related more to art rather than to science. Colour is almost indefinable, and even with dramatic improvements in scientific knowledge, a lot of work is still required.[3]

Authors like Clark (1933) presented the paper mainly on Munsell colour scale of 1905, during the same period the commission international de l'Eclairage (CIE, 1931) published the standards for colour matching.[4] But the absence of valid scientific instruments for colour measurement did not allow significant improvements. Sproull (1973; 1974) published a series of articles in relevant to the three dimensional nature of colour and its relationship with the dental shades.[5]

The desire was to use science express colour and differences in colour numerically. Since the Munsell system had an irregular space distribution, it was not possible to correlate two colours and to calculate the difference between them. In 1976 and 1978 the CIE developed a new system, called CIE LAB (CIE, 1978)[6] In which for the first time it was possible to express colour in numbers, and calculate the differences between two colours using a formula that gives one number as a value of colour differences.[3] For example, CIE LAB values of an object in two different lightening conditions or CIE LAB values of two different objects were measured and the colour difference them was calculated as ΔE.

This so called ΔE[7] value became critical in colour science as well as in the colour industry ranging from textiles to dentistry (Clarke, 1983)

$$\Delta E = [(L_1-L_2)^2 + (a_1-a_2)^2 + (b_1-b_2)^2]^{1/2}$$

Visual colour determination by comparison of patient's tooth with a commercially available dental shade guide, is the most frequently applied method in clinical practice. However, colour reproduction via this process has been found unreliable and inconsistent. Some factors originated from subjective nature of human colour observation affect this process, such as individual differences in physiological and psychological responses to radiant energy stimulation, experience, environmental and lighting conditions. Furthermore, there are several reported disadvantages of commercial shade guides, such as the un-systematical distribution, inadequate range of available shades, and a lack of proper control of various batches of one shade guide from the same manufacturer. Additional, discrepancy in the colour of porcelain powder of the same nominal shade from various manufactures and metamerism also add to the complexity of the colour-matching task.

Nevertheless, during the last two decades, the colorimeter has been rapidly developed in dentistry. It can offer potential objective and quantitative assessment of tooth colour, independent of examiner's experience and environmental conditions. Colorimeters have provided accurate and repeatable measurements for natural teeth and porcelain samples.

Some studies reported that most devices were currently unsuitable for routine clinical dental application with the limitation in measuring translucent objects and the unreasonable cost/size.

Since technician does not usually see the patient's tooth shade and has to work on the basis of dentist's written prescription, a laboratory communication made by dentist is of utmost importance. Shade guide tabs are thicker than the thickness of porcelain used for restoration and also fluorescence of shade guide is different from that of natural teeth, thus making shade selection more challenging for dentist to obtain a correct shade on the prosthesis.[8-12]

Limitations in shade selection through shade guide, led to development of shade matching instruments which perform objective measurements and rely on computer calculations. These are more repeatable, accurate and rapid than visual shade matching. Photos of teeth with corresponding shade tabs taken with the digital cameras are transferred via mails to the lab, but with the advent of smart phone technology communication via social media like whatsapp forcing to use mobile cameras in communicating the same with the lab person.

T he purpose of this study is to determine the validity of the digital photographs method in matching the colour of human teeth using three different cameras (cameras 1, 2, 3). The hypothesis was that if shade selection can be done through photographic images which are taken through digital camera. It is less expensive as compared to spectrophotometers and may provide the entire spectrum of colour space for natural teeth and act like a guide for teeth continuity, translucency, staining / characterization with reference to adjacent teeth. Hence it would be objective method of shade selection and efficient tool for communication with a dental laboratory.

MATERIALS AND METHODS

As study subjects, a total of 126 dental students of Indian origin belonging to different states and different age groups, who are students of GITAM dental college and hospital, visakhapatam, AP were randomly selected. The inclusion criteria were subjects of dentulous and aged 18-25 years, completely dentate arch with presence or absence of third molars and natural maxillary anterior teeth in good alignment. Exclusion criteria include subjects with restoration of maxillary anterior teeth by a complete or partial veneer crown / composite restorations, extensive carious lesions, incisal wear, tooth fracture and gingival hyperplasia, previous orthodontic treatment or orthognathic surgery, congenital or surgical facial defects and any anomalies of the teeth. Oral prophylaxis and polishing was performed 6 days before the study.

PROCEDURE:

Each subject was made to seat upright with the head supported by a head rest on a chair, and in natural head position. It is the standardized and reproducible position, of the head in an upright posture, the eyes focused on a point in the distance at eye level, which implies that the visual axis is horizontal.[13]Then the photographs of teeth, with the corresponding shade tab were taken with the three cameras used in the study.

Three commercially available digital cameras used are.

1. Nikon D 3100 (DSLR), Nikon D 3100 with 14.2 MP, DX Format, lens of 18-55mm, CMOS image, ISO- 200 and a shutter speed of 1/4000 seconds.[Fig 1]
2. Sony digital camera DSC-W210, steady shot with 12.1 MP [Fig 2]
3. Phone camera (Lenova) VIBE X2, 13MP, Ambient light sensor [Fig 3]

Fig 1: Nikon D3100 DSLR

Fig 2: Sony DSC-W210

Fig 3: Lenova VIBE X2

As the difference in mega pixels of the cameras will alter only the height and width of the image and hence the resolution of all the three cameras were standardised to 1080 * 1920

.Most digital still cameras acquire red, green and blue image information that is utilized to create a colour image. The RGB colour model is an additive model in which red, green and blue light are added together in various ways to reproduce a broad array of colours[14]

Colour information received from digital cameras is device-dependent, i.e. the actual colour information (usually presented in red–green–blue or RGB colour space) is different among different devices. Proper calibration and colour adjustment among the digital devices is required for accurate colour management. In this study, the device dependent colour images of input devices (i.e. digital cameras) were converted to a standard device-independent colour space (i.e. CIE LAB)

Fig 4: Digital photographs of the patients' right maxillary central incisor along with the corresponding shade tab

Factors considered while taking a photograph for the study

1. If subject was wearing bright coloured clothing, were draped with a neutral coloured cover (Blue / Gray), because colour balance changes the overall mixture of colours in an image and is used for colour correction.
2. Subjects were made to remove lipstick and other make-up items, as well as eye wear.
3. Teeth should be moist, the subjects must lick their teeth constantly to keep them moist
4. The operatory light was turned off.
5. The room light conditions are maintained , by using light meter (Sekonic L-208 TWINMATE) which was measured in lumen per square meter (lux)
6. Values are obtained by squinting because the cones are better for value and colour than the rods that are being utilized more when we are not squinting.
7. After 10 seconds, looked at grey or blue colour before trying another shade tab.

For all colour measurements in this study spectral reflectance were obtained from 380 to 780 nm that is within the visible spectrum, with 2 nm interval and all the photographs were taken during 12 noon to 1pm in the afternoon, as it is reported that visible spectrum is constant during mid- noon. .Cheek retractors were used to enable adequate lighting to enter the oral cavity.[15]

Digital photographs of the patients' right maxillary central incisor along with the corresponding shade tab were directly placed next to the target tooth [Fig 4]

Digital images thus obtained from the three commercial cameras using their respective digital sensors were then transferred from the camera to a computer, saved as JPG files, displayed on a computer screen. A grid is used to divide the right maxillary central incisor into 9 segments. The middle segments of cervical, middle and incisal parts of maxillary central incisor were taken as colour patches. Each image was opened in Microsoft paint, using colour picker tool RGB values in the middle segments of the maxillary tooth and shade tab were obtained for all the images obtained from the three cameras.

So the device dependent RGB values of colour images of input devices (i.e.; 3 digital cameras) were converted to a standard device-independent colour space (i.e. CIE LAB) using colour math software.[Fig 7, 8]Thus tooth and corresponding shade tab data values were collected.

Vita Easyshade compact (Vita Zahnfabrik, Bad säckingen, Germany)

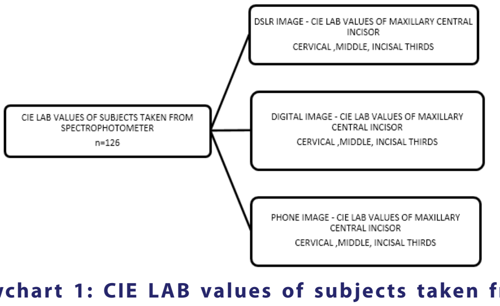
The Vita Easy shade [Fig 5] (Vident, Brea, California) is a cordless, portable, and light weight hand-held spectrophotometer that consists of a hand piece connected to a base unit by a mono coil fiber optic cable assembly .The contact probe tip is approximately 5 mm in diameter. Light from the halogen bulb in the base unit is directed into the tooth surface and tooth is illuminated by the periphery of the tip. A combination of various filters and photodiode arrays receive the light as it is directed through the return fibers located in the centre of the probe tip. Through this arrangement, spectral reflectance of the scattered light is essentially measured in 25 nm bandwidths.

Fig 5: VITA easy shade

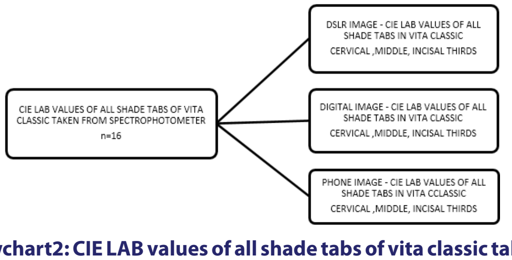
Fig 6: Vita shade guide designation of right central incisor

By using this, the right maxillary central incisor is selected and placing the tip of the spectrophotometer hand piece directly on the tooth. A button is pressed, and the display presents the closest Vita shade in the classical or 3D shade guide designation [Fig 6] Similarly spectrophotometer tip is directly placed on all the shade tabs available in the VITA classic shade guide. Correspondingly the CIE LAB values are obtained from the shade guide designation.

The CIE LAB values thus obtained from the spectrophotometer, from all the subjects as well as from the shade tabs were taken as control groups and are correlated with the CIE LAB values obtained from the images of maxillary central incisor and corresponding shade tabs taken with the three cameras.[flow chart 1, 2]



Flowchart 1: CIE LAB values of subjects taken from spectrophotometer compared with CIE LAB values obtained from the photographs taken with the cameras (1, 2, 3)



Flowchart2: CIE LAB values of all shade tabs of vita classic taken from spectrophotometer compared with the CIE LAB values of all shade tabs obtained from the photographs taken with the cameras (1, 2, 3)

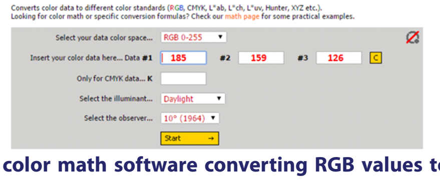


Fig 7: color math software converting RGB values to CIE LAB values #1 : RED ®, #2 : GREEN (G), #3 : BLUE (B)

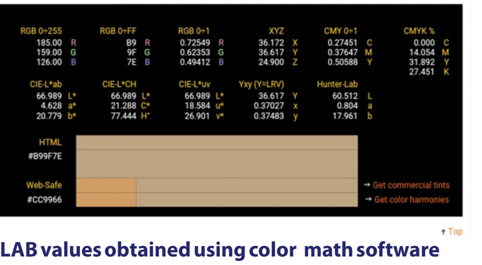
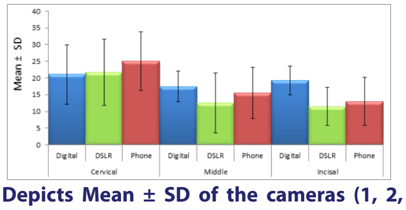


Fig 8 : CIE LAB values obtained using color math software

STATISTICAL ANALYSIS:

TABLE 1: Statistical results of CIE LAB values of subjects taken from spectrophotometer compared with CIE LAB values obtained from the photographs taken with the cameras (1, 2, 3) in the cervical, middle and incisal areas.

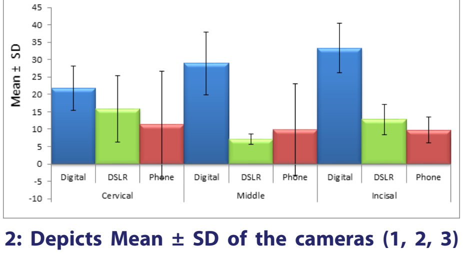
		n	Mean	SD	F-Value	P-Value	Decision
Cervical	Digital	123	21.04613	8.830837	2.245	0.1074	Not Significant
	DSLR	126	21.67417	9.938023			
	Phone	124	25.0208	8.848964			
Middle	Digital	123	17.44423	4.584057	0.9871	0.3737	Not Significant
	DSLR	125	12.51952	8.955739			
	Phone	125	15.49865	7.712015			
Incisal	Digital	122	19.19563	4.310875	8.696	0.0002	Significant
	DSLR	124	11.42387	5.708464			
	Phone	124	12.93382	7.209052			



Graph 1: Depicts Mean ± SD of the cameras (1, 2, 3) in the cervical, middle and incisal areas of the maxillary right central incisor.

TABLE 2: CIE LAB values of all shade tabs of vita classic taken from spectrophotometer compared with the CIE LAB values of all shade tabs obtained from the photographs taken with the cameras (1, 2, 3) in the cervical, middle and incisal areas of maxillary right central incisor.

		n	Mean	SD	F-Value	P-Value	Decision
Cervical	Digital	16	21.76549	6.458979	3.5434	0.037	Significant
	DSLR	16	15.85458	9.572542			
	Phone	16	11.34544	15.38074			
Middle	Digital	16	28.90034	9.051933	26.44	0.000	Significant
	DSLR	16	7.079963	1.539207			
	Phone	16	9.814338	13.12265			
Incisal	Digital	16	33.30798	7.094826	95.398	0.000	Significant
	DSLR	16	12.77779	4.347358			
	Phone	16	9.765106	3.653921			



Graph 2: Depicts Mean ± SD of the cameras (1, 2, 3) in the cervical, middle and incisal areas of the vita classic shade tabs.

RESULTS:

CIE lab values of maxillary central incisor taken through the spectrophotometer directly from the subjects, was compared with the CIE LAB values of maxillary central incisor obtained from the photographs taken with the three digital cameras used in the study and also compared, the CIE LAB values of classical vita shade tabs obtained with the spectrophotometer with the photographs of shade tabs taken with the three digital cameras.

The stability of the colour measurement setup was assessed by examining the colour differences (ΔE) between the variables specified in the flow charts and a one way ANOVA statistical analysis was performed. The table - 1[graph 1] depicts, there exists no significant correlation in the cervical and middle thirds of the maxillary central incisor with the p value of 0.1074 and 0.3737 respectively, where as in the incisal thirds it shows significant values among the three cameras and the digital camera images are the one which showed greatest mean of 19.195 with the p value of 0.0002.

The table-2[graph 2] shows, there exists a significant correlation in the cervical, middle and incisal thirds of shade tabs taken through cameras and spectrophotometer, with the p value of less than 0.005.

DISCUSSION:

Colour has two basic characteristics: Hue and Chroma. Natural tooth colour also displays these same characteristics.

Hue can be defined as the actual colour such, as yellow or gray. Chroma is the intensity of that color and is sometimes called saturation. Hue and Chroma are typically represented by a shade guide in terms of which colour comes closest to the actual tooth being measured. For example, shade guides will have a range of A1 to A4 or B1 to B4, plus C and D shades. In which alphabet represents hue and the number depicts chroma. The draw back with the vita classic is non representation of value, where as that can be overcome in vita 3D master but shade selection using with 3D master is cumbersome.

Value is the brightness of a tooth. It is therefore given a separate classification than colour when communicating shade.

Teeth also exhibit translucency and can be measured by how much light can pass through different sections of a tooth. Shade taking problems arise because most natural teeth are not an exact match to a shade guide, nor do shade guides adequately express tooth translucency and value. In many cases, when it is decided that a tooth has a certain shade, the Hue and the Chroma are communicated to the lab, but never the value and this is where the problems arise. Very few crowns are accepted by the patients, if the value is incorrect, while moderate inaccuracies in chroma and hue may go unnoticed. For this reason the shade taking protocol needs to be based on this information being communicated to the lab in the most accurate way possible

In this experimental setup, each of the three sampled cameras was an experimental unit, in which easy RGB soft ware was used to convert the RGB to CIE LAB values. The variation within each camera in the study can contribute to the colour accuracy.

In a study conducted by Alvin G.Wee and Delwin T. Lindsey16 CIE LAB values of 264 color patches and 65 shade tabs were measured with a spectroradiometer. Digital images of the samples were taken with the Nikon D100, Canon D60 and Sigma SD9 cameras. Shade tab CIE LAB colours were predicted by applying the digital image values into the calibration models and were compared to the measured CIE LAB values. Concluded that Every camera/calibration model (ΔE's ranging from 1.79 to 5.25) showed a statistically significant difference from the colour measurement setup.

when comes to in vivo, that is placing the tip of the spectrophotometer directly on to the tooth surface and correlating with the digital image samples CIE LAB values shows no significant correlation in the cervical and middle one thirds where as significant results are seen in the incisal thirds, this is mostly attributed to the incisal translucency, which shows difference in absorbtion and reflection of lights.

When applying to the shade tabs, shows significant results in all the three gradients this is because of perception of light is different for the values taken from the spectrophotometer directly and to the values obtained from the digital images of shade tabs. The colour measurement with spectrophotometer directly to the tooth or the shade tab is of three dimensional object, where as the photographs taken with the three cameras either to the tooth or the shade tab is an image.

CONCLUSION:

From the previous information, it becomes apparent that accurately assessing colour and shade is a critical component of aesthetic dentistry. This process requires knowledge of the dimensions of colour, the tools used to assess colour and shade, and clinical experience. Digital camera is extremely efficient and easy to use. Digital photography can be an ideal adjunctive tool for the dentist and lab technician to quantify shade. Commercial digital cameras when combined with the appropriate calibration protocols showed potential for use in the colour replication process of clinical dentistry.

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