A Comparison of Tooth Shade Selection between use of Visual Approach, Digital Cameras and Smartphone Cameras

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Abstract

The study aims to determine whether smartphone cameras were comparable to the digital camera in terms of tooth shade selection and to compare the conventional method with the digital method of taking tooth shade selection.

A total sample of Year 4 students (n=45) in the Faculty of Dentistry, Universiti Teknologi MARA(UiTM) were selected. All participants were required to answer a questionnaire consisting of images of the 3D-Vita Classic shade tabs captured by Nikon DSLR D610, iPhone 6 (8MP) and Xiaomi Mi4i (12MP) and direct visualisation of the shade guide. Participants were required to match the images of a tooth shown on the monitor screen with the shade guide provided. Several questions also included a tooth with a known shade guide and participants were required to match the shade via visual approach to the shade guide given. All results were analysed by SPSS Ver. 24 through repeated measure ANOVA.

The mean comparison of images from the shade tab investigated were summarised as: Visual Approach (2.0222) > Xiaomi Mi4i (1.1333) > Nikon DSLR (1.0889) > iPhone 6 (0.6000). They were all significantly different ($p<0.05$) from each other except for the mean result produced between Nikon DSLR versus Xiaomi Mi4i ($p>0.05$).

The images produced by Nikon DSLR, Xiaomi Mi4i and iPhone 6 were less accurate when compared to the conventional visual approach of tooth shade selection. However, images produced by Xiaomi Mi4i were comparable to the images produced by the Nikon DSLR.

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Introduction

Tooth shade selection especially in the anterior region of the oral cavity is an important aspect in dental treatments. Current aesthetic demands require determining a blend of color to suit the patient needs. It was stated that an incorrect choice of shade selection is the second most common reason for replacing a fixed prosthesis.[1,2]

Conventional approaches use the naked eye to match a pre-recorded set of color shades commonly known as shade guides. Unfortunately, it is evident that no standardization was available to fabricate the commercialized shade guides as each manufacturer uses different hues, chroma and value with possibility of different pigments in use.[3,4,5] In addition to that, it's well been documented that use of visual approach to shade selection is affected by external factors such as illumination, oral environment, tooth textures and layers, personal judgment and patient factors.[4,6,7,8,9] This suggests the need of a more consistent and reproducible method in color matching of teeth to its corresponding tooth shade.

Other shade selection methods currently utilized are the spectrophotometers, colorimeters and digital cameras and imaging systems. Advancements in computer technology allow a more reproducible method of tooth shade determination. Besides registering the hue (degree to which a stimulus can be described as red, green, blue and yellow), chroma (saturation or strength of dominance for the hue) and value

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(overall intensity of how light or dark a color is) of the shade taken, the newer methods of shade taking combine all this data to display an array of colors each specific for gingival area, mid teeth and incisal third of teeth. A comparison with the conventional method of shade taking shows a 93% objective shade matching with an increase in 33% accuracy.[10] However, use of these methods require special equipment and can be costly.

The conventional and cheapest method of tooth shade selection is still by matching pre-made existing shade guides, but its weaknesses are apparent. The incorporation of digital cameras with pre-existing shade guides may compensate for these weaknesses. It was proposed that using DSLR created images in conjunction with a conventional shade guide would overcome the drawbacks of spectrometer and colorimeter.[11] Improved communication between clinician and dental technician could be achieved especially in terms of shade, texture, light transmission and other related factors (i.e. root treated teeth, metal stump) that may have effect on color distribution.[12]

Studies have shown that successful tooth shade matching may vary between 53% to 71%.[13,14] Previous studies have shown that digital images were acceptable and superior to the conventional visual method in determining tooth shade.[12,15] These studies however have certain limitations, such as small number of observers, a smaller number of shade tabs and different camera setup settings which might cause variations or bias in results of the study. One study concluded that reliability of color matching with digital images is influenced by the illuminants and camera's white balance setups.[16] Limited studies were available when smartphone cameras were used to determine tooth shade.[17,18] A study suggested that it was possible to retrieve shade selection via smartphone cameras with some modifications on the shade guide being used. A different way of classification was proposed.[17] Another compared shade accuracy results of iPhone 5, two different DSLR cameras, The Nikon D700 and the Canon EOS 30 D and also the Samsung S3 smartphone in which the results showed that the iPhone 5 was the least accurate for shade determination and the other appliances were comparable.[18] As smartphones nowadays get more sophisticated and enhanced technology driven, it's interesting to note that use of smartphone cameras especially its camera may aid in tooth shade selection.[19]

1.1 Aims and Objectives

The purpose of this study was to determine whether smartphone cameras were comparable to the digital cameras in terms of tooth shading selection and to compare the conventional method of tooth shade selection with a digital method. Advantages such as standardization and improved communication with dental technicians and the patient may be eminent. Not much is known on the matter thus our study aims to fill this gap in knowledge. The null hypothesis is the tooth shade selection between images produced by the smartphone cameras, DSLR cameras and the conventional method (Visual) of tooth shade selection having no significant differences.

Materials and methods

2.1 Method Overview

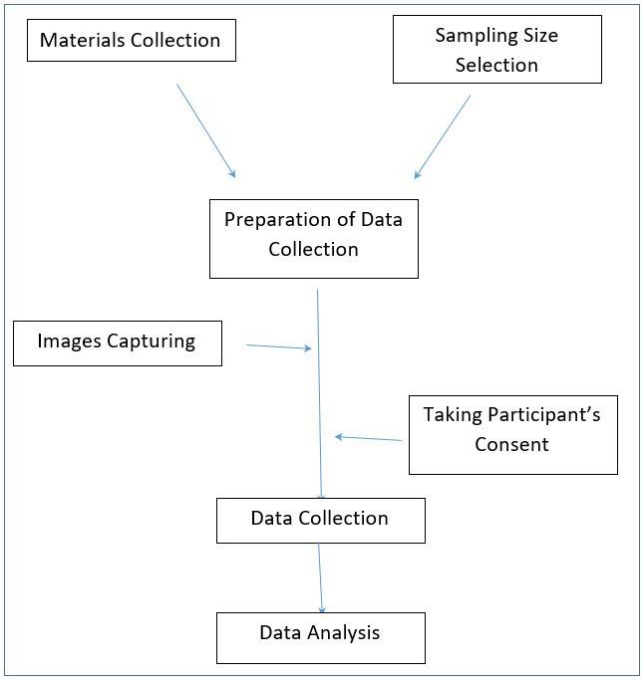

Figure 1. Flowchart of the steps undertaken in this study

Figure 1 shows a flowchart of the way this present research was conducted. The steps undertaken to compare tooth shade selection via smartphone cameras, digital camera and visual were as follows:

a. First, a total sample size (n=53) consisting of year 4 dental students of UITM were chosen

to participate in this study. All participants were given a consent form and an explanation on how the study will be conducted. Participants who refused to participate were not included in the study.

b. Each participant was required to answer a questionnaire (20 questions) in an OSPE-like scenario as shown in Figure 2. Each question was given 30 seconds to be answered and all answers were recorded.
c. OSPE stations consisted of 20 questions of a known tooth shade (VITA Shade Classical) and 4 rest stations. 15 questions were displayed on the computer monitor (Lenovo) with a standardized display setting (100% brightness, 1280 x 720 resolution), 5 more questions were displayed with an unknown tooth shade tab to match it with its identical shade in the shade guide given as shown in Figure 3.

All results were analysed using Repeated Measure Analysis of Variance (ANOVA), Statistical Package of Science Study (SPSS) software Version 24.

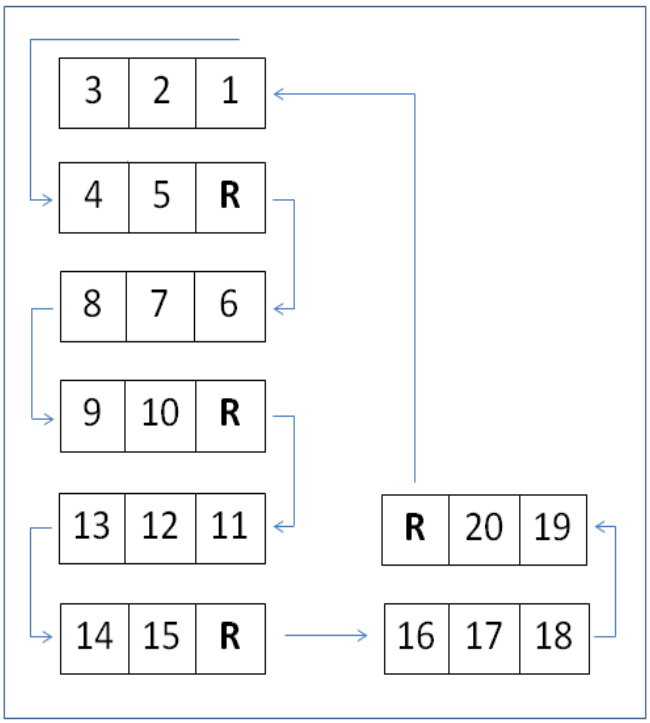

Figure 2. Illustration of the participants movement from station to station. The order of participant movement to the subsequent stations after 30 seconds was in accordance with the arrow illustrated.

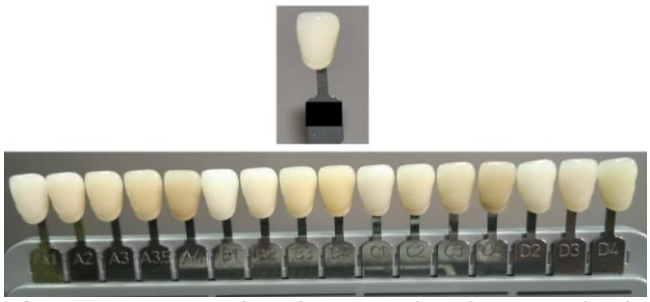

Figure 3. Example of covered unknown shade tab to be matched with shade guide given.

2.2 Material Preparation

The images of the shade tabs were captured using an Android smartphone camera (Xiaomi Mi4i), iPhone camera (iPhone 6) and a digital camera (Nikon D610).

The images were captured under a predetermined standardized condition to produce clear images. The standard conditions consisted of a fixed shooting distance between the shade guide position and the camera for both smartphone cameras and the DSLR. A light source was emitted at a 45° degree in front of the shade tab placed before imaging was performed. The distance between the shade tab and the camera was fixed to 14cm for both Android and iPhone cameras and 25cm for the DSLR respectively. The position of the light, shade tabs and the camera are illustrated in Figure 4. The images captured were then cropped to fit only the shade tabs. The shade guide was also captured via the same condition using those devices.

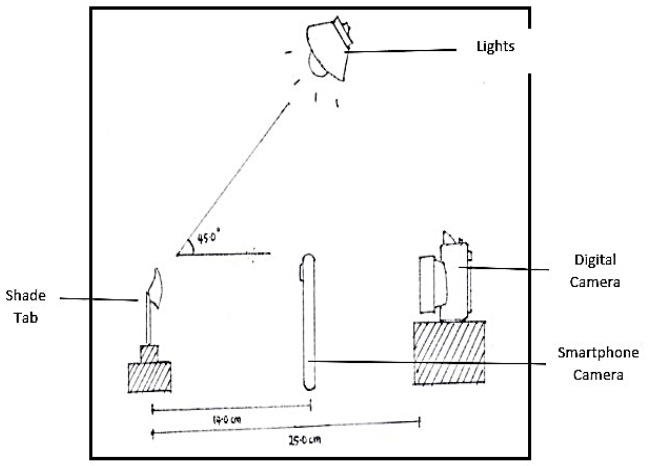

Figure 4. The illustration shows the standardized position of each material used to produce the best image.

2.3 Data Collection

A number of 24 stations were prepared for this study including 4 rest stations. In these rest stations, the participants will be provided with blue-screened desktop monitors. This is to neutralize their vision and reduce their vision fatigue from all the tooth shade matching done. Out of 24 stations, only 19 stations were provided with desktop monitors and another 5 stations used visual approach questions.

All procedures were conducted in the morning to get a result while participants were still energetic and fresh. The answers for each station were divided into two; alphabets and numbers (ie A5) in the box provided in the answer sheet given to them. This corresponds to the manufacture shade guide tabs utilized. All participants were given 30 seconds for each station. The bell was rung to signal the end of the allocated 30 seconds as shown in Figure 2. The answers would only be considered as true when BOTH alphabetical and numeric were correct. The data were analysed using Repeated Measure Analysis of Variance (ANOVA).

Results

3.1 Descriptive Analyses

Based on our analyses, the mean value for correct answer by participants was the highest for the visual method which is 2.0222. Mean value for the DSLR and Android phone (Mi4i) were 1.0889 and 1.1333 respectively. iPhone 6 scored the lowest mean score which is 0.6000. A summary of these values is shown in Table 1 and Figure 5.

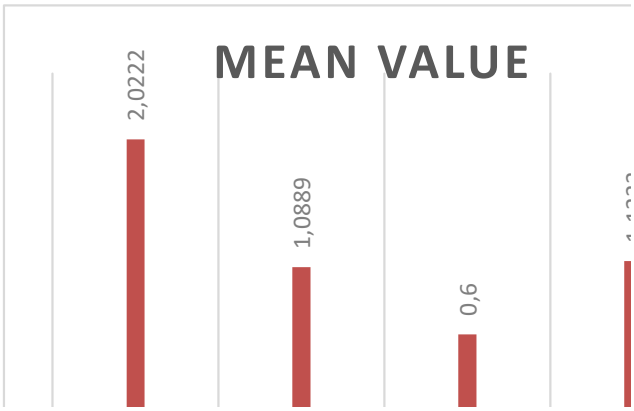

Figure 5. A bar chart of the mean value of correct answer by participants.

3.2 Statistical Analyses

There was no significant difference between the DSLR and Mi4i (p value = 0.803). Other comparisons had shown significant difference between them, Visual and DSLR (p value = 0.000), Visual and iPhone 6 (p value = 0.000), Visual and Mi4i (p value = 0.000), DSLR and iPhone 6 (p value = 0.003), and Iphone 6 and Mi4i (p value = 0.002). A summary of these values is shown in Table 2.

Descriptive Statistics

	Mean	Std. Deviation	N
Visual	2.0222	1.03328	45
DSLR	1.0889	.73306	45
iPhone	.6000	.57997	45
Mi4i	1.1333	.99087	45

Table 1. Mean values for the correct answers for each approach.

Pairwise Comparison

(I) type	(J) type	Mean Difference (I-J)	Std. Error	Sig.[b]
Visual	DSLR	.933*	.186	.000
	Iphone 6	1.422*	.184	.000
	Mi4i	.889*	.234	.000
DSLR	Visual	-.933*	.186	.000
	Iphone 6	.489*	.158	.003
	Mi4i	-.044	.177	.803
Iphone 6	Visual	-1.422*	.184	.000
	DSLR	-.489*	.158	.003
	Mi4i	-.533*	.158	.002
Mi4i	Visual	-.889*	.234	.000
	DSLR	.044	.177	.803
	Iphone 6	.533*	.158	.002

Table 2. Mean difference value between each approach. (The mean difference is significant at the .05 level)

Discussion

The correct interpretation of tooth colour plays a fundamental role in decisions regarding aesthetic treatments.[20] With the variable morphology of the human teeth, it is unrealistic to believe that natural tooth colour matching would not induce some errors in measurement. It would be the same for this study as participants used a shade guide that consists of a variety of colours. As for the visual approaches, there were additional factors that would interfere with the outcome such as experience and colour education. Human colour perception also depends on ageing, gender, ocular fatigue, clinician colour deficiency, the integrity and level of ocular and cerebral functions.[21] This study employs standardizing experience and colour education for each participant, by selecting participants from the same year of studies to remove any bias as mentioned in the methodology.

Although literature shows that visual colour matching is not reproducible from the same participant from one day to another, our current study does support these findings. The results from the mean value of each approach concluded that the Visual approach has the highest mean value of 2.0000 as compared to the other approaches. As it is the most frequently used method for shade selection in dentistry, this result is consistent to that of other studies in which visual assessment using shade guide was proven to be a valid and a reliable approach.[20] However, achieving 100% accuracy visually is difficult as it may be affected by multiple interferences mentioned earlier.

As for the mean value of the Nikon Digital Camera D610, it was lower than the Xiaomi Mi4i, 1.0222 and 1.0889 respectively but not significantly different. A previous study had shown that the accuracy of method comprising shade gradation and texture for comparison using digital camera was comparable to that of colorimeter or spectrophotometric analysis, which concluded that digital camera would be a reliable tool for dental shade matching.[11] As the Android phone (Xiaomi Mi4i) was not significantly different in mean value when compared to the NIKON Digital Camera D610, it can be said that the Xiaomi Mi4i was comparable to that of Nikon Digital Camera D610. This outcome may be due to the Xiaomi Mi4i camera sensor having the resolution of 12 megapixels which allows the images produced by the Xiaomi Mi4i to be comparable with images of Nikon Digital Camera D610 in terms of tooth shade selection.

On the other hand, iPhone 6 holds the lowest mean value out of the four approaches. This may be due to the iPhone 6 having 8 megapixels resolution for its camera. The results could be improved by utilising a camera resolution of the same or higher resolution than 12 megapixels, for example the iPhone 7, iPhone 8 and iPhone X in future studies. This would improve the image quality produced by the smartphone. However, from this result, it showed that the iPhone 6 camera was not comparable to that of the other approaches tested in this study.

This study has its limitations. As pointed out by Tam *et al. 2012*, illumination by use of flash has effect on tooth shade determination.[11] Our study did not use the flash with the DSLR due to this reason, but it could be suggested that use of flash might improve the results of the DSLR. Nevertheless, for standardization purposes, use of flash was not utilized for smartphone cameras as well. Limited resources were available, hence results of using improved technology within digital cameras would give different outcomes. It remains an interesting topic for futures studies. A possible suggestion might be to place a tooth shade guide beside the tooth for the shade to be determined and then obtain a digital photograph.[11] Participants could then be instructed to determine the shade with the pictures provided. A modification of a digital shade guide may also be useful.[16] Although this study shows that use of visual assessment remains the best method for tooth shade selection, use of digital images holds promise as an alternative or support.

Conclusions

The images produced by Nikon DSLR D610, Xiaomi Mi4i and iPhone 6 were less accurate when compared to the conventional visual approach of tooth shade selection. However, images produced by smartphones with a minimum 12 Megapixel cameras were comparable to the images produced by the Nikon DSLR D610. With the increase in technology, smartphone cameras and digital cameras hold promise as a viable tool for tooth shade selection.

Declaration of Interest

The authors report no conflict of interest.

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