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Original Article

Dentistry Section

Evaluation of Shade Matching Accuracy of Smartphone Application compared to Conventional Visual Method: An Observational Pilot Study

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ABSTRACT

Introduction: Shade selection has been always a challenging step for a dentist by using a shade guide in manual visual selection. "Colour Grab" application of the smartphone simplifies the procedure of shade selection by providing L a* b* values.

Aim: To evaluate the accuracy of the Smartphone application in shade selection compared to the visual method of shade selection.

Materials and Methods: This observational pilot study was conducted at Maratha Mandal Dental College, Belagavi, Karnataka, India, from January 2022 to March 2022. A total of 30 subjects were examined by five observers for shade selection using two methods- 1. Conventional visual method, 2. Smartphone application. A total of 300 samples were collected by the both methods. Colour grab application was used to determine L a* b* values of Vita Classic Shade tabs at a distance of 25 cm on neutral grey background and tabulated. Data was collected and subjected to statistical analysis. Cronbach's alpha test for interobserver reliability analysis, intraclass correlation test and Spearman rho correlation tests were used to determine the inter-observer and intra-observer shade selection accuracy respectively.

Results: A total of 30 subjects (Females-16, Males-14) of age between 18-40 years were observed and analysed. For observers 1, 2, 3, 4, and 5, the correlation coefficients were 0.962, 0.849, 0.824, 0.930 and 0.793, respectively at p-value <0.01 for all observers which was highly significant. This test showed that there was strong correlation between the two techniques for each observer which had excellent consistency.

Conclusion: Colour Grab smartphone application can be used as an alternative method to conventional visual method in shade selection.

Keywords: Colour grab application, Shade selection, Vita classical shade guide

INTRODUCTION

The natural tooth shade selection is a crucial step in fabrication of any dental prostheses. Selection of tooth shade via conventional technique involves a considerable subjective discrepancy from observer to observer. Dental shade matching appliances like colour grab, image colour identifier, colour harmony, the Dental Maintenance Plan (DMP) dental chromatcher, T shade have been brought into the market to overcome imperfections and inconsistencies of traditional shade matching such as the visual method, like the conventional shade guide and its derivative shade guides. Metamerism, inadequate conditions of colour matching, tools and practitioner's eye fatigue are the inbred difficulties that are present in visual method of shade selection [1].

Over the last decade, different technology-based shade matching instruments have been available in the market to facilitate shade matching but they possess the disadvantage of increased expenses. Recently, mobile applications that can analyse the colour of objects are available. Dental shade matching by using digital technology may be feasible when the components of a colour are properly manipulated [2]. Visual thresholds such as perceptibility and acceptability can be quantified only by combining visual and instrumental colour measurement methods [1].

In 1976, the International Commission on Illumination defined the CIELAB system also referred to as L a*b* system, as a perpetual uniform space, wherein change in colour corresponds to a numerical change. The L refers to perceptual lightness a*, b* correspond to various primary colours of vision: red (+a*) and green (-a*), blue (-b*) and yellow (+b*) respectively [3]. Separating the colour features into L a* b* values facilitate favourable matching while using mobile applications [4]. The "Colour Grab" application on the smartphone for dental colour matching simplifies the process by providing L a* b* values which aid in an accurate shade selection, provided the environmental settings which are optimised. Shade variations on a single tooth can also be detected using the application hence allowing better guidance to the clinician to select a shade in order to fabricate a more realistic aesthetic prosthesis. Smartphone cameras, even those without internal setting features, can be used as shade measuring instruments when appropriate lighting settings are employed by simplifying the challenges of the conventional technique of shade selection [2]. In the present study, an attempt had been made to simplify the method using software like mobile apps available for use with android and can be downloaded from the appstore for free so that the user will know the required shade very immediately. The aim of present study was to evaluate the accuracy of the smartphone application in shade selection compared to the visual method of shade selection.

MATERIALS AND METHODS

This observational pilot study was conducted at the Department of Prosthodontics and Crown and Bridge, Maratha Mandal Dental College, Belagavi. After obtaining the ethical clearance, the study was conducted from January 2022-March 2022.

Inclusion criteria: A well-formed, healthy anterior teeth with good patient's co-operation were included in the study.

Exclusion criteria: Hypoplastic, discoloured and crowded teeth and teeth with previous restorations were excluded from the study.

Sample size calculation: As per the minimum requirement for the pilot study, a total of 30 subjects were examined by 5 observers to do the shade selection in two methods:

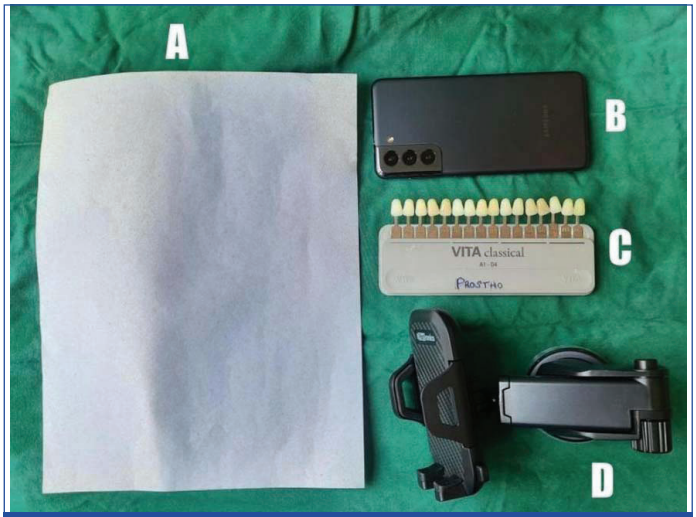
1. Conventional visual method.

2. Through smartphone application.

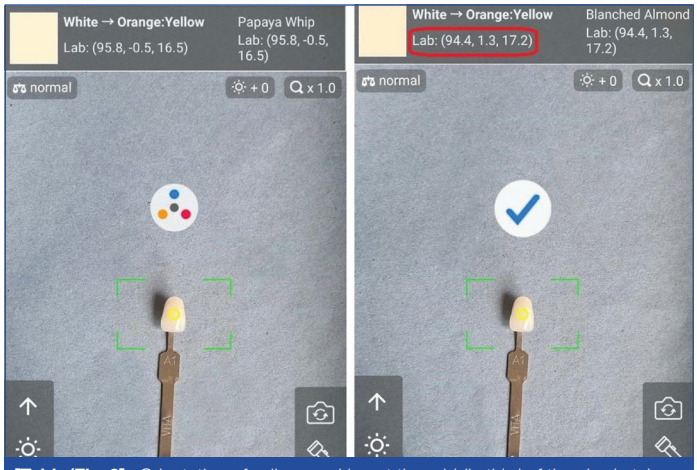
Five post graduate students from the Department of Prosthodontics and Crown and Bridge were selected as observers who were experienced in shade selection for two years. The observers were unaware of the shade selected by their counterparts in both techniques of shade selection. Thirty patients with good to fair oral hygiene and no anterior teeth crowding or restorations were chosen for shade matching tests. Prior consent was taken regarding their participation in the study. Professional cleaning was advocated in the upper anterior teeth region (canine to canine) before the shade selection.

Procedure

A smartphone application Colour Grab (version 3.9.2 © 2021 Loomatix Ltd.) and a smartphone camera (Samsung s21, 64 megapixels) was used along with Vita classic shade guide to collect the Lightness (L), red/green value (a) and blue/yellow (b) values of individual shade tabs in an optimised environment. A Grey solid background (4 munsells), natural light (during noon) was used for optimisation of the environment. [Table/Fig-1]. The individual shade tabs were positioned within the frame of the camera till central yellow marking in the application was set at the middle-third of the shade tab [Table/Fig-2]. Once stabilised, the yellow marking changes to a blue tick mark with L a, b values registered at the top of the application window. The readings were recorded for individual shade tab. [Table/Fig-3,4]. The observers were provided with a chart containing the predetermined L a, b values of individual shade tabs as given in [Table/Fig 4]. With same optimised conditions as visual method, each observer correlated the L a, b values of the tooth as determined through the Colour Grab application with the customised L a, b value for that particular shade tab as previously determined and tabulated in [Table/Fig-4] in order to select a shade [Table/Fig-5,6].



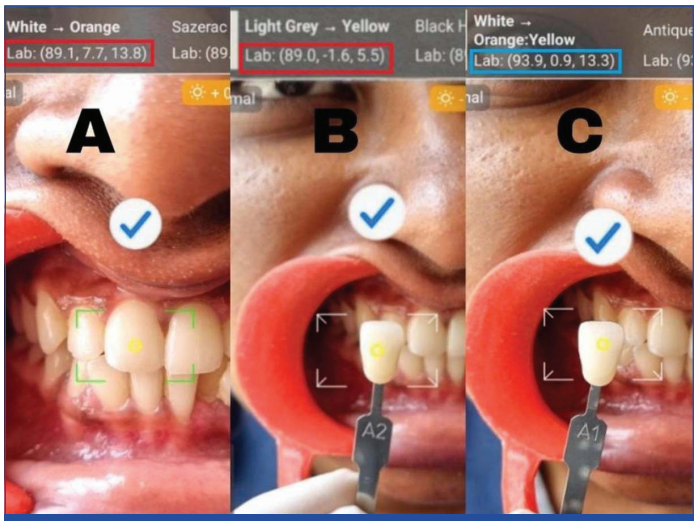
[Table/Fig-1]: Materials used- A) Neutral grey background; B) Mobile Phone Camera with Colour grab app installed; C) Vita Classic shade guide; D) Mobile phone stand.



[Table/Fig-2]: Orientation of yellow marking at the middle third of the shade tab.
[Table/Fig-3]: Tick mark appears on proper orientation and L a b recorded for each shade tab as marked in red. (Images from left to right)

Individual shade tab values			
Shade	**L**	**a**	**b**
A1	94.4	1.3	17.2
A2	91.9	2.5	18.8
A3	92.2	1.4	27.5
A3.5	90.5	3.4	29.5
A4	90.6	3.4	29.1
B1	96.6	1.8	16.6
B2	94.7	1	22.3
B3	93.5	0.7	27.4
B4	92.5	1.3	26.4
C1	94.6	0.9	17.1
C2	91.9	2.1	23.3
C3	90.5	3.2	25.1
C4	88	4.5	28.9
D2	94.1	1.3	15.7
D3	90.7	2.4	23.8
D4	91.4	1.7	24.5

[Table/Fig-4]: Individual shade tab values using Colour Grab Application.
L-lightness; a-red/green value; b-blue/yellow value



[Table/Fig-5]: A) L a* b* values of the selected tooth; B) L a* b* values of shade tab A2 matches with the tooth shade; C) comparison with A1 shade. L a* b* values marked in blue, closest values determine the shade.

Shade selection through application (Group B)					
	Observers				
Patient number	**Observer 1 (A)**	**Observer 2 (B)**	**Observer 3 (C)**	**Observer 4 (D)**	**Observer 5 (E)**
1	A3	A3	A3	A3	A3
2	A3	A3	A3	A3	A3
3	B3	B3	B2	B3	B3
4	A1	A1	B2	A1	A1
5	A3	A3	A3	A3	A3
6	A2	A2	A2	A2	A1
7	B2	B2	B2	B2	B2
8	A2	A2	A1	A2	A1
9	C1	C1	B1	B1	C1

10	B2	B2	B2	B2	A1
11	A3	A3	A3.5	B4	A3.5
12	A3.5	A3.5	A3.5	A3	A3.5
13	A2	A2	A2	A2	A2
14	A3	A3	A3	A3	A3
15	A1	A1	A1	A1	A2
16	A2	A2	A2	A2	A2
17	A2	A2	A2	A2	A1
18	A1	A2	A2	A2	A2
19	A2	A2	A2	A2	A2
20	A3.5	A3.5	A3	A3	A3.5
21	A2	A2	A2	A1	A2
22	A3	A3	A3	A3	A3
23	A1	B2	A1	A1	A1
24	A3	A3	A3	A2	A2
25	A2	A2	A1	A1	A2
26	A1	A1	A1	A1	A1
27	A2	A2	A2	A2	A2
28	A1	A1	A2	A1	A1
29	A1	A2	A2	A1	A1
30	A1	A1	A1	A1	A1

[Table/Fig-6]: Shade selection using colour grab application by five observers for 30 subjects.

The two methods for shade selection were as follows:

Shade selection of the tooth using visual method: The patient was seated in an upright position facing north on a dental chair. The observer was asked to determine the shade of upper central incisor from an eye distance of 25 cm from the tooth during shade selection. Each observer determined the shade of 30 subjects and selected shades were tabulated [Table/Fig-7]. If the shade selected by more than three observers were same, that shade was considered to be the shade of the tooth.

Conventional method of shade selection (GROUP A)						
S. No.	Patient number	Observers				
		Observer 1 (A)	Observer 2 (B)	Observer 3 (C)	Observer 4 (D)	Observer 5 (E)
1	1	A3	A3	A2	A3	A2
2	2	A3	A3	A3	A3.5	A3.5
3	3	B3	B3	B2	B3	B3
4	4	A1	A1	A1	A1	A1
5	5	A3.5	A3	A3	A3.5	A3.5
6	6	A2	A2	A2	A2	A1
7	7	B3	B3	B2	A2	A2
8	8	A2	A2	A1	A2	A1
9	9	C1	C1	B1	B1	C1
10	10	B2	B2	B2	B2	B2
11	11	A3	A3	A3.5	A3.5	A3.5
12	12	A3.5	A3.5	A3.5	A3	A3.5
13	13	A2	A2	A2	A2	A2
14	14	A3.5	A3.5	A3.5	A3	A3
15	15	A1	A1	A1	A1	A2
16	16	A2	A2	A2	A2	A2
17	17	A2	A2	A2	A2	A1
18	18	A2	A1	A1	A1	A2
19	19	A2	A2	A2	A2	A2
20	20	A3.5	A3.5	A3	A3	A3.5
21	21	A2	A2	A2	A1	A2
22	22	A3	A3	A3	A3	A3
23	23	A1	A1	A1	A1	A1
24	24	A3	A3	A3	A2	A2
25	25	A2	A2	A1	A1	A2
26	26	A1	A1	A1	A1	A1
27	27	A2	A2	A2	A2	A2
28	28	A1	A1	A2	A1	A1
29	29	A1	A2	A2	A1	A1
30	30	A2	A1	A1	A1	A2

[Table/Fig-7]: Shade selection by the observers for 30 subjects using conventional visual technique.

Shade selection of the tooth using smartphone application: The yellow marking of the application window was positioned in a manner to orient to the centre of the middle-third of the tooth. It was stabilised until the yellow marking changes to a blue tick mark. In the present study, the camera distance of 25 cm from the shade tab was used for optimisation of the environment [5]. Optimised lighting conditions were used in this study, but in general clinical situations, the lighting conditions vary and there is no means to standardise the values for each situation. As the lighting conditions change, the specific values of each shade tab also changes. A total of 300 samples were collected from 30 subjects.

Interobserver Reliability Analysis was done for shade selection using conventional and smartphone application by using Cronbach's alpha test.The cut off of Cronbach's alpha was given in [Table/Fig-8].

Cronbach's alpha	Internal consistency
a ≥0.9	Excellent
0.9>a≥0.8	Good
0.8>a≥0.7	Acceptable
0.7>a≥0.6	Questionable
0.6>a≥0.5	Poor
0.5>a	Unacceptable

[Table/Fig-8]: Cut off of Cronbach's alpha Interpretation: Excellent consistency between observers in both techniques.

STATISTICAL ANALYSIS

The statistical analysis was performed using International Business Management (IBM) Statistical Package for Social Sciences (SPSS) statistics for windows, version 25.0 (IBM Corp, Armonk, New York, USA). Cronbach's alpha statistical test was applied for Interobserver Reliability Analysis. Intraclass correlation test was applied to determine the shade selection accuracy between observers in both techniques. Spearman rho correlation test was applied to the observations recorded by the individual observers for both the techniques. The p-value of <0.05 was considered statistically significant.

RESULTS

Two groups A and B, based on the method of shade selection were categorised in which each group consists of 30 subjects (females-16, males-14) of age between 18-40 years. The mean age and standard deviation were given in [Table/Fig-9]. A total of five observers were selected to carry out the shade selection. Assessment of inter-observer reliability analysis for shade selection was done by Cronbach's alpha test. Cronbach's alpha test analysis were 0.964 and 0.935 by conventional technique and mobile app technique respectively [Table/Fig-10]. This revealed that there is excellent consistency between observers in both techniques [Table/Fig-8]. Intraclass correlation test for conventional technique was 0.842 and for app technique was 0.741. In both

techniques, results were highly significant (p≤0.01). This suggests substantial agreement within the observers in both techniques [Table/Fig-11]. Spearman rho test was applied to individual observers for both techniques. For observers 1, 2, 3, 4, and 5 the correlation coefficients were 0.962, 0.849, 0.824, 0.930 and 0.793 respectively at p-value <0.001. This test showed that there was high significance and strong correlation between the two techniques for each observer [Table/Fig-12].

Age	Female (n=16)	Male (n=14)
Mean (years)	28.25	29.78
SD	6.54	4.33

[Table/Fig-9]: Age distribution of all participants.

Technique	Cronbach's alpha
Conventional technique	0.964
App technique	0.935

[Table/Fig-10]: Reliability Analysis (interobserver) for shade selection. Statistical test applied: Cronbach's alpha.

Technique	Intraclass correlation	p-value
Conventional technique	0.842	**<0.001**
App technique	0.741	**<0.001**

[Table/Fig-11]: Statistical test applied: Intraclass correlation test; HS- Highly significant at p<0.01.

Spearman's rho	Correlation coefficient with app	p-value
Observer 1 Conventional	0.962**	**<0.001**
Observer 2 Conventional	0.849**	**<0.001**
Observer 3 Conventional	0.824**	**<0.001**
Observer 4 Conventional	0.930**	**<0.001**
Observer 5 Conventional	0.793**	**<0.001**

[Table/Fig-12]: Correlation tables: Statistical test applied: Spearman rho; HS- Highly Significant at p<0.01 Interpretation: Very strong correlation between two techniques; Bold p-values are significant

DISCUSSION

The colour of an object is determined by light that enters the human eye from that object. What is commonly known as "the colour of a tooth" is actually the colour of the reflected light perceived by the human visual system. Retina consists of a cell layer which reacts to light stimulation and is made of rods and cones. The eye can differentiate up to 300 spectral colours provided, considerably more light is available to activate the cones. Hence for every aesthetic dentist, it is challenging to determine and replicate the appearance of teeth. It requires patience, perseverance and good visual perception to mimic teeth to its closest form and detail [5]. In dentistry, colour is communicated on a regular basis but often misunderstood. Shade selection is determined by visual and scientific components however, every human eye does not have the same capacity of perceiving it in a standardised manner [6]. Fondriest J stated that after continuous light is incident on the retina and light is removed from the retina instantly, the receptors continue to be active and send signals to the brain for a short period of time. This is known as spreading effect. An alteration in perception is caused by an after image which is a physiologic effect of normally functioning receptors. The fatigue of cone receptors leads to negative after image as they become insensitive to further stimulation. [7]. This is why, when shade selection is done by using shade tabs close to a tooth, it is necessary to decide the appropriate shade within seconds.

Brunescence as defined by Pensler AV is the natural browning of the cornea that occurs with age and acts as a filter, changing the appearance of colours. Hence apart from features of the tooth, the ability of the clinician's eye to differentiate the shades based on hue, chroma, value is also essential in the process of shade matching [8,9]. Since shade selection is dependent on subjective perception of the clinician's eye, any discrepancy during this process can lead to a restoration that does not match the patient's existing dentition rendering it unesthetic [8]. Using an additional aid like smartphone application in such a situation can be a boon to a dentist to provide a patient with an excellent prosthesis as shade selection is the primary requisite for a successful prosthesis.

Albert CJ et al., assessed colour in dental prosthesis using smartphone. They aimed to use photographs taken with smart phones to ease the process of shade selection for the dental surgeon. VITA 3D MASTER shade guide was used on a single tooth photograph for colour assessment. The study concluded that although it is a complementary method to conventional method, smartphone tools are capable of minimising possible failures in shade selection [10]. Mohammadi A et al., studied the validity and reliability of colour selection by smartphone photography using two smartphone applications and Adobe Photoshop software on Vita Lumin Vacuum and 26 shade tabs of Vita 3D Master. The study concluded that high validity and reliability is observed when shade taking is done by calibrated smartphone pictures and Adobe Photoshop [11]. A prospective clinical study was conducted by Raza F et al to determine the reliability of software application in natural teeth shade selection and concluded that software applications offered reliability and repeatability in shade selection [12]. In the current study, the observations derived from the results were consistent with previous studies that smartphone application for selection of shade is reliable and complementary method to conventional visual shade matching using shade tabs. This method can be used in situations where there is eye fatigue, reduced capacity of a clinician to differentiate between shades, and artificial illumination conditions, provided the values of the shade tabs using the application are predetermined in the existing illumination situation [13]. The application can be used even in smartphones without internal camera settings.

Limitation(s)

Sample size was small. Only upper central incisors were used for shade determination so further studies need to be done on larger sample size and on different teeth, as shade variations are seen among different teeth segments.

CONCLUSION(S)

The Colour Grab smartphone application was accurate and a very simple method in selecting the shade. The reliabilty analysis for both the methods of shade selection was excellent with chronbach's alpha score 0.964 for conventional method and 0.935 for app technique. The primary goal of a successful prosthesis is excellent aesthetics and patient satisfaction. To achieve this, shade selection plays a pivotal role. "Colour Grab" application of the Smartphone simplifies the procedure of shade selection by providing L a* b* values. To design and implement new and appropriate smart apps, professional requirement regarding shade matching need to be identified by researchers and software companies. Further studies need to be conducted to evaluate the application in different light conditions in order to be used in regular practice.

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