OPEN ACCESS

ORIGINAL ARTICLE

EVALUATION OF SHADE SELECTION ACCURACY: A COMPARATIVE STUDY USING SMARTPHONE CAMERAS AND VISUAL METHOD

[1]SAQIB NAEEM SIDDIQUE, [2]PALWASHA BABAR, [3]AIMEN USMAN, [4]IRSAM HAIDER, [5]MARYAM VIRDA, [6]RAYYAN SAMEER

ABSTRACT

Objective: *To assess the accuracy of shade selection through smartphone cameras using a smartphone application and to compare the results with the visual method.*

Methodology: *Two VITA classical A1-D4® shade guides (VITA North America) were used, one as a control and the other as a test shade guide in which the tabs were masked to hide the shade color and arranged randomly. Each of the 30 participants selected the best shade match of the test tabs with the control shade guide. For digital shade matching, shade tabs of the shade guide were individually mounted and pictures were taken using three different smartphones and the Lab values were recorded using Color Picker® App. The shade code of the reference tab with the smallest color difference from the test tab was manually identified and labeled as the correct match.*

Results: *The visual method achieved 56.9% correct shade matching while it was 77.08% by the digital method. Individually, it was 87.5% , 93.75% and 50% for phone A, B and C respectively. The comparison among the three phones showed a statistically significant difference in the results of phone C.*

Conclusion: *Color Picker® app offers a successful and straightforward way for dental shade selection. The results enforce that utilizing a smartphone application for shade matching could be a practical approach for selecting shades in a dental clinic.*

Keywords: *Dental esthetics, smartphone apps, digital technology*

This article may be cited as: Siddique SN, Babar P, Usman A, Haider I, Virda M, Sameer R. Evaluation of shade selection accuracy: A comparative study using smartphone cameras and visual method. Pak Oral Dent J 2024; 44(1):65-68.

INTRODUCTION

Over the past few years, there has been a significant rise in esthetic standards and expectations by the patients. This makes shade selection for rehabilitating anterior teeth, a crucial and challenging task. Despite the advancements in dental shade selection techniques, the process remains difficult for dentists with implications for the final esthetic results.[1]

The conventional method of shade selection is through visual shade matching but it has its limitations. Factors like variance in the clinician's color perception and experience, eye fatigue, ambient light condition, the background of the tooth and the shade guide affect the outcome. These make this method highly subjective to achieve precise and consistent results in dental restorations.

Advancements in technology have allowed a more consistent approach to determine tooth shade. Digital shade-matching technologies have been developed to address these issues and provide more accurate and reliable color matching in dental procedures. These objective techniques include shade matching instruments like spectrophotometer, colorimeter, digital cameras and graphic softwares.[2] Dental spectrophotometer offers the most accurate and precise results and is considered a gold standard for tooth shade selection.[3]

[1] Dr Saqib Naeem Siddique, Assistant Professor, Operative and Paediatric Dentistry, University College to Dentistry, The University of Lahore Email: saqibns@gmail.com

[2] **Corresponding author:** Dr Palwasha Babar, Assitant Professor, Paediatric Dentistry, Fatima Memorial Hospital College of Medicine and Dentisry, Lahore Email: palwasha_i@hotmail.com Cell: 0334-8740767

[3] Dr Aimen Usman, Demonstrator, Operative and Paediatric Dentistry, University College of Dentistry, The University Of Lahore

[4] Dr Irsam Haider, Assistant Professor, Operative and Paediatric Dentistry, University College of Dentistry, University College of Dentistry, The University of Lahore

[5] Dr Maryam Virda, Assistant Professor, Operative and Paediatric Dentistry, University College of Dentistry, University College of Dentistry, The University of Lahore

[6] Dr Rayyan Sameer, Community and Preventive Dentistry, University College of Dentistry, The University of Lahore

Received for Publication: Jan 1, 2024
Revised: Feb 14, 2024
Approved: Feb 16, 2024

The desire for more aesthetically pleasing dental restorations among patients, coupled with dentists' hesitancy to invest in costly equipments, has prompted researchers to explore new technologies for budget-friendly alternates. The use of smartphones has been investigated in this regard. They offer an accessible, portable, cost-effective, easier and convenient mode of recording for shade selection. Dentists can use the built-in cameras to capture precise images of teeth efficiently, saving time and money compared to specialized equipment. This accessibility and convenience make smartphones a practical choice for dental professionals. In order to have an objective analysis of the color, the International Commission on Illumination established the CIELAB system, which also known as the Lab system, where alterations in color are represented by numerical adjustments.[4] In this framework, the color space is defined by three coordinates: L, a, and b. The "L" coordinate pertains to the degree of lightness, spanning from 0 for black to 100 for white. The "a" coordinate corresponds to the position along the red-green axis, with positive values representing the red color spectrum and negative values denoting the green color spectrum. Meanwhile, the "b" coordinate signifies the position along the yellow-blue axis, with positive values indicating the yellow spectrum and negative values indicating the blue spectrum. This removes the subjectivity in shade matching. Lab values make it easier to achieve favorable matches when utilizing mobile applications.[5] There have been advancements in mobile applications capable of analyzing the color of a specific image segment and identifying its components based on the selected color space.[6] The current study employs a smartphone app 'Color Picker' that is designed to identify color and record Lab values.

A lack of research exists concerning the utilization of smartphone cameras to determine tooth shade. The present study aims to assess the accuracy of shade selection through smartphone cameras using a smartphone application and to compare the results with the visual method.

METHODOLOGY

An in-vitro experimental study was conducted at the University College of Dentistry, The University of Lahore from January to April 2022. The study protocol was approved by the Institutional Ethical Review Board (UCD/ERCA/21/11he).

Visual Shade Matching:

The study enrolled 30 participants after getting informed consent. A convenience sample of dentists with normal color vision was included comprising specialists, post-graduate residents/demonstrators and house officers (10 in each group). During the shade-matching procedure, the participants were seated upright on a chair at the same room area at the same time of the day. Two VITA classical A1-D4® shade guides (VITA North America) were used, one as a control and the other as a test shade guide in which the tabs were masked to hide the shade color and arranged randomly. Each of the participants was asked to select the correct shade match of the test tabs with the control shade guide.

Digital Shade Matching:

VITA classical A1-D4® shade guide (VITA North America) was used in the study. For digital shade matching, all sixteen shade tabs on the shade guide were individually mounted on a custom setup and pictures were taken using different and the Lab values were recorded using Color Picker® App on three different Android smartphones: Phone A (Samsung A50;13MP camera, 28mm sensor-size), Phone B (Samsung A5; 25MP camera, 26mm sensor size), Phone C (Infinix Note 8; 64MP camera, 14mm sensor size). Photographs were taken in a predefined standardized environment to ensure the production of standardized, clear images. The phones were adapted on a tripod stand placed 15cm from the mounted shade tab under uniform illumination with auto-mode settings and no flash. Lab values were recorded for each shade tab and served as reference values of shade selection for that smartphone. In the next step, the shade code on each test tab was masked and the sixteen shade tabs were individually mounted on the custom setup. CIELAB values were re-recorded for each tab using different smartphones. A color difference (ΔE) was calculated between the CIELAB values of reference tabs and test tabs using the CIELAB formula.

$$\Delta E = ((L1^*-L2^*)2 + (a1^*-a2^*)2 + (b1^*-b2^*)2)0.5$$

The shade code of the reference tab with the smallest color difference from the test tab was manually identified and labeled as the correct match. Data was analyzed using SPSS version 21. The number of correct shade selections were recorded for each method. Chi-square test was applied for comparison of the accuracy of digital and visual shade matching methods. P-value ≤ 0.05 was considered significant.

RESULTS

Among the thirty participants for visual shade matching, 46.7% (n=14) were males and 53.3% (n=16) were females. The total percentage of correct shade matching results from the visual method was 56.9% (n=273/480). Among the study participants, consultants had 61.9% correct shade matches but the comparative results showed that the difference was not significant statistically with other participants. The results of the visual shade selection method for the respective group of participants are summarized in Table 1.

A total of 16 shade tabs were assessed by each of the three phones. The percentage of correct shade selections by the digital method was 77.08% (n=37/48) collectively and it was 87.5% (n=14/16), 93.75% (n=15/16) and 50% (n=8/16) for phone A, B and C respectively. The comparison among the three phones showed a statistically significant difference in the results of phone C (p-value=0.014) while no significant difference between phone A and B was observed. (p-value=0.827).

The p-value for comparison between visual and digital shade selection methods was calculated to be 0.26.

TABLE 1: THE RESULTS OF THE VISUAL SHADE SELECTION METHOD AND COMPARISON OF THE ACCURACY OF THE RESULTS AMONG DIFFERENT GROUPS OF PARTICIPANTS

Participants	Correct results % (n)	p-value*
Consultants	61.9 (99)	0.213
Demos/PGR	53.1 (85)	0.812
House Officers	55.6 (89)	0.501

*Chi-square test; p-value <0.05 considered significant

DISCUSSION

Inaccurate selection of shade is the second most prevalent cause for the replacement of a fixed prosthesis.[7] The perception of color in humans is influenced by factors such as age, gender, ocular fatigue, clinician color deficiency, and the the condition and function of both the eyes and the brain.[8] Therefore, it is impractical to expect that matching natural tooth color would not introduce certain errors in measurement.

Our study observed 56.9% correct shade matching through visual technique and 77.08% through digital technique. In another comparative study conducted at Aga Khan University Hospital, Pakistan, the accuracy of shade selection by visual method was reported to be 39.4% and that by digital method to be 66%. However, the current study reported superior results for the visual method.[9] The inclusion of research participants who were enrolled in both studies may explain the discrepancy. While the first study included general dentists and dental assistants, the current study enrolled both dentists and consultants. Moreover, the methodology of digital shade matching is different for both studies as the previous study employed a digital camera for shade selection.

The use of instruments like spectrophotometers and digital cameras were introduced with satisfactory accuracy in shade matching, but the accompanied heightened cost and the need for equipment adjustment and maintenance limits its use in routine. Smartphones present a superior option due to their accessibility, ease of use, and advanced image-processing capabilities for precise shade matching. Smartphone applications are being developed by dental companies in order to utilize the built-in, high-resolution cameras of smartphones to simplify shade matching in dental clinics. A comprehensive systematic review of the literature concluded that instrumental shade selection aids such as spectrophotometers, digital cameras, or smartphones showed significantly improved shade selection in comparison with the conventional shade guides.[10] The findings in the present study align with those of previous research, indicating that smartphone applications for shade selection are a reliable and complementary method to conventional visual shade matching using shade tabs.[11,12]

A study compared the results of two smartphones (iPhone 5 and Samsung S3) and two digital digital cameras (Nikon D700 and Canon EOS 30D). The results showed that iPhone 5 gave least accurate results while the results of others were comparable.[13] Another study had similar findings and concluded that the images taken with a minimum of 12MP smartphone cameras were comparable to the images produced by the digital camera (Nikon DSLR D610).[14]

An interesting finding of our study was that contrary to the expectations, Phone C with highest resolution camera (64MP) did not give accurate shade matching. The reason lies in the small aperture and sensor size crammed with high-resolution cameras. This adds more noise to the picture as individual pixels get affected by the adjacent pixel's light.[15] Therefore the sensor size is an important consideration for image quality of a smartphone camera.

The findings of a recent systematic review and meta-analysis revealed that regardless of the type of color measurement tool used, be it a spectrophotometer or a digital camera, a higher likelihood of inaccurate shade matching was observed when using the traditional method based on shade guide tabs.[16] This highlights an ongoing trend of inferior results linked to the traditional methodology and raises the possibility of more practical alternatives in dental shade-selecting techniques. In contrast, the Lab* color space system, as used in the current study, has emerged as a superior alternative for precise and standardized communication of color shades, minimizing subjective interpretation errors in dental practices. Modern shade-taking techniques combine the information from recording the hue (the amount of red, green, blue, and yellow), chroma (saturation or intensity of the hue), and value (overall lightness or darkness) of the captured shade to present a spectrum of colors specifically designed for the gingival region, mid teeth, and incisal third of teeth. This method exhibits a 93% objective shade matching when compared to the conventional shade-taking strategy.[17]

One of the limitations to the use of smartphones in digital shade selection is the standardization of the light conditions. The illuminants and white balance settings of the camera have an impact on how reliably colors may be matched using digital photographs.[18] It has been proven that the digital shade selection using smartphones is consistent and reproducible under standardized light intensity.[19] Methods for standardizing the light source in such devices are currently absent, posing a potential risk of color mismatches and challenges in color communication and documentation. Different adjuncts are being explored in this regard to optimize the light conditions. A study by Jorquera and colleagues reported that the results of the smartphone camera using a light correcting device were comparable to the digital camera.[20] With these advancements, it can be confidently asserted that the future of shade matching lies in the utilization of smartphones.

Our study has a few limitations which include a small sample size, lack of standardization of light conditions while using smartphones and reproducibility of the results were not assessed. However, the study provides a foundation for further research on the topic.

CONCLUSION

Color Picker® app provided a precise and easy way for shade selection. The findings of the current study enforce that utilizing a smartphone application for shade matching could be a practical alternative to the use of spectrophotometers and other digital shade selection methods in a clinical setup.

REFERENCES

1 Tabatabaian F, Beyabanaki E, Alirezaei P, Epakchi S. Visual and digital tooth shade selection methods, related effective factors and conditions, and their accuracy and precision: A literature review. J Esthet Restor Dentist. 2021 Dec;33(8):1084-104.

2 Kalpana D, Sharan S, Sreeharsha TV, Chandra P, Badola I. A review on digital shade matching technologies. Int J Sci Res. 2019 Jan;8(1):24-6.

3 Alnusayri MO, Sghaireen MG, Mathew M, Alzarea B, Bandela V, Sghaireen MG. Shade selection in esthetic dentistry: A review. Cureus. 2022 Mar 20;14(3):e23331.

4 Xiao K, Liao N, Zardawi F, Liu H. Investigation of Chinese skin colour and appearance for skin colour reproduction. Chin Opt Lett. 2012;10(8):e083301.

5 Agrawal V, Kapoor S. Colour and shade management in esthetic dentistry. Univers Res J Dent. 2013;3(3):120-7.

6 Moussa R. Dental Shade Matching: Recent technologies and future smart applications. J Dent Health Oral Res. 2021;2(1):1-10.

7 Delania M, Odang RW, Tanti I. The effect of light and dual cure resin cement to the color change of esthetic restoration porcelain laminate veneer. J Int Dent Med Res. 2017; 10(3): 964-9.

8 Nasruddin M, Zulkifeli NN, Ariffin SS, Subra MM, Ismail M, Yassin M. A comparison of tooth shade selection between use of visual approach, digital cameras and smartphone cameras. J Int Dent Med Res. 2021;14(1):99-104.

9 Siddique SN, Khan FR, Babar P. Comparison of tooth shade matching using visual and digital camera methods. Pakistan Oral & Dental Journal. 2019 Jul 28;39(2):184-8.

10 Morsy N, Holiel AA. Color difference for shade determination with visual and instrumental methods: a systematic review and meta-analysis. Syst Rev. 2023 Jun 8;12(1):95.

11 Hari TS, Thonse EP, Hallikerimath RB, Melavanki CL, Nayak AK, Ruttonji Z.Evaluation of shade matching accuracy of smartphone application compared to conventional visual method: An observational pilot study. J Clin of Diagn Res. 2022; 16(12):27-31.

12 Tam WK, Lee HJ. Accurate shade image matching by using a smartphone camera. J Prosthodont Res. 2017;61(2):168-76.

13 Yuh AW. Comparison of color accuracy of commercial digital cameras and cellular phonecameras for laboratory purposes. 2014. PhD dissertation, West Virginia University, Available at: https://researchrepository.wvu.edu/etd/179

14 Nasruddin M, Zulkifeli NN, Ariffin SS, Subra MM, Ismail M, Yassin M. A Comparison of tooth shade selection between use of visual approach, digital cameras and smartphone cameras. J Int Dent Med Res. 2021;14(1):99-104.

15 Sajjadi SH, Khosravanifard B, Moazzami F, Rakhshan V, Esmaeilpour M. Effects of three types of digital camera sensors on dental specialists' perception of smile esthetics: a preliminary double-blind clinical trial. J Prosthodont. 2016 Dec;25(8):675-81.

16 Hardan L, Bourgi R, Cuevas-Suárez CE, Lukomska-Szymanska M, Monjarás-Ávila AJ, Zarow M, et al. Novel trends in dental color match using different shade selection methods: a systematic review and meta-analysis. Materials. 2022 Jan 8;15(2):468.

17 Paul S, Peter A, Pietrobon N, Ha¨mmerle CH. Visual and spectrophotometric shade analysis of human teeth. J Dent Res 2002; 81: 578–82.

18 Tung OH, Lai YL, Ho YC, Chou IC, Lee SY. Development of digital shade guides for color assessment using a digital camera with ring flashes. Clin Oral Investig. 2011; 15(1): 49-56.

19 Raza FB, Kumar VA, Jacob A, Ali A. Assessment of a smartphone-based software application as a potential digital tool in tooth shade selection: a prospective clinical study. Quintessence Int. 2021 Jul 1;52(7).

20 Jorquera GJ, Atria PJ, Galán M, Feureisen J, Imbarak M, Kernitsky J, et al. A comparison of ceramic crown color difference between different shade selection methods: visual, digital camera, and smartphone. J Prosthet Dent. 2022 Oct 1;128(4):784-92.

CONTRIBUTIONS BY AUTHORS

1 Saqib Naeem Siddique:	Study conception and design, data analysis, supervision of research, review of final manuscript.
2 Palwasha Babar:	Data analysis and interpretation, literature review, manuscript writing, and final version approval.
3 Aimen Usman:	Data collection, statistical analysis, wrote the first draft
4 Irsam Haider:	Data interpretation and statistical analysis, reviewed the final manuscript
5 Maryam Virda:	Interpretation of results, literature review, critical revision.
6 Rayyan Sameer:	Interpretation of results, reviewed the final manuscript.