ORIGINAL ARTICLE

# Evaluation of Shade Selection Precision Utilizing Smartphones among Clinical Dental Students: A Cross-sectional Study

**Arwa Alkhalifah[1], Lien Abdallah[2], Tala Alnaji[2]**

*[1]Department of Restorative Dentistry, College of Medicine and Dentistry, Riyadh Elm University, Riyadh, Saudi Arabia, [2]Department of General Dentistry, College of Medicine and Dentistry, Riyadh Elm University, Riyadh, Saudi Arabia*

## Abstract

**Background:** Accurate shade selection is essential for achieving optimal esthetic outcomes in restorative dentistry. With the increasing availability of smartphone technology, its use as an adjunct for shade selection warrants evaluation, particularly in academic and resource-limited settings. **Aim:** This study aimed to evaluate the accuracy of smartphone-based shade selection, with and without flash, in comparison with the conventional visual method among clinical dental students and interns. **Materials and Methods:** A cross-sectional study was conducted among 102 female dental students in their 5th and 6th years and dental interns. Participants assessed the A3 shade from the VITA Classical shade guide under three conditions: Visual assessment in natural daylight, smartphone photography with flash, and smartphone photography without flash. The VITA Easyshade spectrophotometer served as the reference standard. Data were analyzed using the Chi-square test to compare accuracy among the three methods. **Results:** The visual daylight method demonstrated the highest accuracy, with 71.8% correct identification of the A3 shade. Smartphone photography without flash showed an accuracy of 22.5%, while smartphone photography with flash demonstrated the lowest accuracy at 5.6%. A statistically significant difference was observed among the three methods ($P < 0.001$), indicating that flash usage adversely affects color perception. No significant differences in accuracy were found across the clinical levels of participants. **Conclusion:** Visual shade selection under natural daylight remains the most reliable method among dental students and interns. Smartphone photography without flash may serve as a practical adjunct in academic or resource-limited environments; however, its accuracy is inferior to the visual method. The implementation of standardized digital protocols may enhance reliability and promote the integration of technology in dental education.

**Key words:** Dental students, esthetic dentistry, shade selection, smartphone photography, visual method

## INTRODUCTION

An esthetically pleasing smile, according to patients, is dependent on multiple different factors and is constantly changing with the trends, making the concept of the "perfect smile" a very subjective matter.[1] However, recently, there has been a notable shift in esthetic dentistry towards a more natural approach to the conceptualization of esthetics, specifically regarding tooth color, for both patients and dentists.[2] Therefore, selecting the appropriate tooth shade to achieve the desired natural look for patients is critical and can be challenging, as multiple factors are recognized. Some of these factors include the degree of transparency and opacity of the teeth, the dentist's level of experience, eye fatigue levels, and lighting conditions.[3]

One of the most common tools used for shade selection is the VITA classical A1-D4 ® (Vita Zahnfabrik, Bad Säckingen, Germany), which was created in 1956. It consists of tabs of 16 shades arranged numerically according to hue, chroma, and value.[4] Other effective approach involves the utilization of instruments such as spectrophotometers, which have been demonstrated to offer superior accuracy compared to traditional visual shade guides.[5] Dentists use shade guides

**Address for correspondence:**
Arwa Alkhalifah, Department of Restorative Dentistry, College of Medicine and Dentistry, Riyadh Elm University, Riyadh, Saudi Arabia.
Phone: 00966-920000842.
E-mail: arwa.alkhalifah@riyadh.edu.sa

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under standardized lighting conditions for best results. Light conditions significantly impact shade selection, making proper light source selection crucial.[6]

Research showed that visual shade selection yields the most predictable results using traditional methods under standardized lighting.[7] As digital and tele-dentistry grows, smartphone camera use in esthetic dentistry has become popular among dental students due to its convenience.[8] Smartphone cameras are becoming prevalent as alternatives to more precise devices. Therefore, they can help in initial shade evaluation and patient interaction.[8] Tooth shade selection is crucial in restorative dentistry, significantly influencing restoration success.[3] Although the traditional method of selecting shades visually remains an essential skill for dental professionals.[9] Educational attainment and training in shade matching are crucial for accuracy. Research shows dental professionals should engage in hands-on courses and continuous education to enhance shade-matching skills.[10,11]

Nowadays, Smartphone technology is playing an important adjunct role in the shade selection process to improve accuracy and reproducibility. The utilization of Smartphone cameras and other digital cameras has received special preference due to their easy access and use, along with the objective nature of the colour measurement through software analysis. However, these technological innovations face challenges of calibration, lighting standardization, and environmental influence on image acquisition. At present, literature lacks accuracy and reliability of the smartphone technology compared to the visual method in shade selection. Hence, this research gap needs investigation on tooth shade selection.

As lighting conditions are fundamental in shade selection, there is a large gap in studies comparing the use of smartphone photography with or without flash, as opposed to the proven accuracy of natural daylight. Therefore, this cross-sectional study aimed to evaluate the difference in the accuracy of tooth shade selection between the traditional visual method, smartphone photography with or without flash, and the use of a Vita Easyshade spectrophotometer according to shade value, chroma, and hue among dental students in their 5$^{th}$ and 6$^{th}$ years and interns.

The specific objectives of this study were to compare the accuracy of shade selection using a smartphone camera with and without flash among dental students at different academic levels. Second, we evaluated the impact of smartphone photography on the selection of a specific shade (A3) from the VITA Classical shade guide. Our null hypothesis posits that dental students' accuracy in selecting shades will not show a significant difference when using a smartphone camera, irrespective of the flash being activated or not.

## MATERIALS AND METHODS

### Study design

This cross-sectional study was conducted in a controlled environment within the REU dental clinic. Participants assessed the selected A3 shade from the VITA Classical shade guide using visual shade selection under natural daylight (control), smartphone camera with flash, and smartphone camera without flash. A Vita Easyshade spectrophotometer was used to confirm the accuracy of shade selection [Figure 1].

### Participants

This comparative cross-sectional study was conducted among clinical students at the College of Medicine and Dentistry, Riyadh Elm University, Riyadh, Saudi Arabia, following the acquisition of ethical approval from the Institutional Review Board of the Research and Innovation Centre (IRB number: FUGRP/2025/410/1226/1113). The study focused on clinical female students (5$^{th}$, 6$^{th}$ year, and interns) who were attending the dental clinics at the Namuthajia campus and treating patients under supervision.

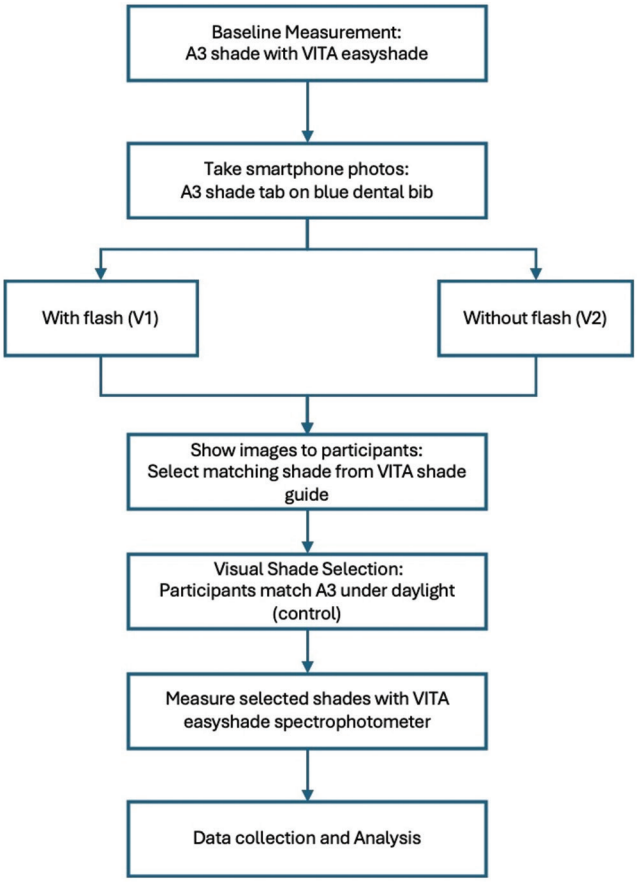


**Figure 1:** Flow chart of the study design

### Criteria

Female dental students without color vision deficiencies were selected for this study. In contrast, students with known color blindness or any condition affecting their color perception were excluded from the study. Written informed consent was obtained from all participants.

### Sample size

A priori power analysis for a chi-square test with two degrees of freedom, an effect size of w = 0.32, and an alpha level of 0.05 indicated that a minimum sample size of 102 participants would achieve a statistical power of 0.83. This sample size was estimated in accordance with the previous reported study by Jouhar in 2022.[10]

### Study procedure

#### *Baseline measurement*

The Vita Easyshade spectrophotometer with shades served as a standard reference, as shown in Figures 2a and b. In addition, the A3 shade tab was employed for comparative analysis between the groups.

#### *Smartphone photography*

The A3 shade tab was placed against a blue dental bib background to cut down on color distractions and lessen eye strain. Photographs were taken with flash and without flash using an iPhone 14 camera, as shown in Figure 3a and b.

#### *Shade matching process*

All participants were provided with a VITA Classical shade guide to choose the shade corresponding to the presented image. Subsequently, the participants visually matched the actual shade tab under natural daylight conditions (12 PM–1 PM) without prior knowledge of the correct shade [Figure 4].

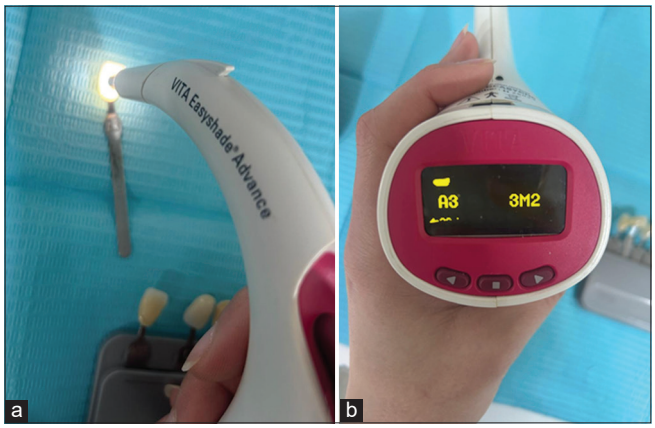


**Figure 2:** (a) Measuring shade A3 with a spectrophotometer. (b) Confirmed shade tab A3

#### *Accuracy confirmation*

Once shade was selected, their identification codes were matched to a VITA classical shade guide. The numbers of the chosen shade tabs were recorded, and the accurate matches were determined. The shade tabs selected under all three conditions were measured and compared for the accuracy of each method.

### Statistical analysis

All the collected data were entered into an Excel spreadsheet and then transferred to a specialized statistical software program (Statistical Package for the Social Sciences Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp.). The frequency distribution and percentages were calculated for categorical variables. A Chi-square test (Fisher's exact test) was applied to compare the shade values selected by clinical dental students using different methods. A $P$ <0.05 was considered statistically significant for all tests.

## RESULTS

Table 1 shows the descriptive data on the distribution of participants. The study comprised 102 participants equally

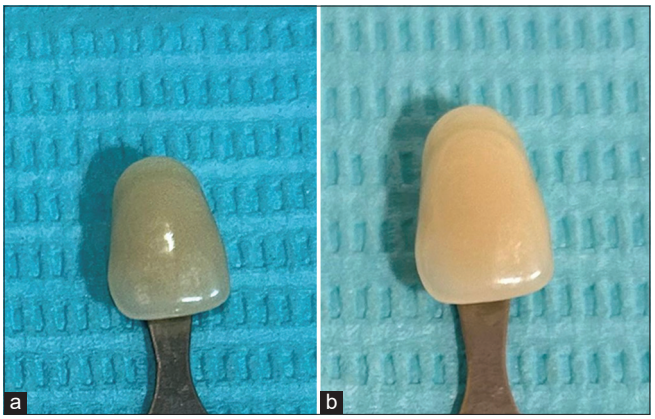


**Figure 3:** Smartphone photos: (a) A3 tab with flash. (b) A3 without flash


**Figure 4:** Visual shade selection method showing covered A3 shade tab

distributed among the academic levels, such that there were 34 (33.3%) from the 6th year, 34 (33.3%) from the 5th year, and 34 (33.4%) interns.

The distribution of dental shades under the three conditions (With Flash, Without Flash, and Control) selected by the participants is presented in Table 2. The visual method (control, 50%) for determining the main shade (A3) was the most prevalent, followed by the no-flash image method (15.7%) and the flash method (3.9%). Four and 16 participants correctly identified the A3 shade with and without the use of the flash image, respectively. The conventional method was the most precise, with 51 subjects selecting the correct shade. Of the 102 participants, 71 correctly identified the A3 shade. B3 was the second-highest shade, following A3 with 44 respondents choosing it. For the B3 shade, 19.6%, 10.8%, and 12.7% of the participants correctly disclosed it using the without flash, with flash, and conventional methods, respectively. Eighteen respondents correctly detected the B4 shade using the flash. The A3.5 shade was identified most accurately by 22 participants using the no-flash method. In contrast, the visual method most frequently resulted in the selection of shade A3. Shade selection showed a statistically significant difference across the different methods ($P < 0.001$) [Table 2].

**Table 1:** Distribution of the study participants

| Participants | *n* | % |
|---|---|---|
| 6th year | 34 | 33.3 |
| 5th year | 34 | 33.3 |
| Interns | 34 | 33.4 |
| Total | 102 | 100.0 |

Table 3 displays a comparison between A3 and other shades without flash, with flash, and using the conventional method. The chi-square test indicated a highly significant difference in shade selection across the groups ($\chi^2 = 65.620$, df = 2, $P < 0.001$), with A3 being far more correctly identified by the participants in the control group compared to the flash and no-flash groups.

Table 4 shows shade selection with and without the use of flash. It was noted that the shade A3 was selected more commonly without the use of flash (80.0%) than with flash (20.0%), and revealing a statistically significant difference ($\chi^2 = 7.983$, df = 1, $P < 0.005$).

Table 5 illustrates the dental shade selections among 5th and 6th-year students and interns using the flash, without flash, and visual methods. The A3 shade was the most frequently chosen shade overall and within the control group. When using flash, shades A4 and C4 were selected more often, whereas the A3. 5 shade was more commonly chosen without flash by 5th-year students and interns.

Table 6 shows A3 versus other shade selections across different clinical years. The chi-square test revealed no significant differences in A3 versus other shade selections using the flash ($\chi^2[2]=0.520$, $P=1.000$), no flash ($\chi^2[2]=1.038$, $P = 0.595$), and visual ($\chi^2$ [2] = 0.706, $P = 0.703$) methods across the clinical years of the study participants.

## DISCUSSION

This study examined the selection of tooth shade using an iPhone camera with and without the use of flash and compared these methods to the traditional visual approach.

**Table 2:** Participants' shade selection by different methods

| Shade | With Flash | | Without Flash | | Control | | Total | | *P* |
|---|---|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % | *n* | % | |
| A3 | 4 | 3.9 | 16 | 15.7 | 51 | 50.0 | 71 | 23.2 | <0.001 |
| A2 | 1 | 1.0 | 8 | 7.8 | 9 | 8.8 | 18 | 5.9 | |
| A3.5 | 10 | 9.8 | 22 | 21.6 | 3 | 2.9 | 35 | 11.4 | |
| A4 | 17 | 16.7 | 8 | 7.8 | 1 | 1.0 | 26 | 8.5 | |
| B2 | 2 | 2.0 | 1 | 1.0 | 1 | 1.0 | 4 | 1.3 | |
| B3 | 11 | 10.8 | 20 | 19.6 | 13 | 12.7 | 44 | 14.4 | |
| B4 | 18 | 17.6 | 14 | 13.7 | 2 | 2.0 | 34 | 11.1 | |
| C2 | 3 | 2.9 | 3 | 2.9 | 8 | 7.8 | 14 | 4.6 | |
| C3 | 7 | 6.9 | 4 | 3.9 | 4 | 3.9 | 15 | 4.9 | |
| C4 | 13 | 12.7 | 1 | 1.0 | 2 | 2.0 | 16 | 5.2 | |
| D2 | 1 | 1.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 | |
| D3 | 7 | 6.9 | 0 | 0.0 | 6 | 5.9 | 13 | 4.2 | |
| D4 | 8 | 7.8 | 5 | 4.9 | 2 | 2.0 | 15 | 4.9 | |

The null hypothesis, positing no significant difference in shade selection accuracy using a smartphone camera with or without flash, was rejected.

The current study findings confirm the superiority of the visual method of shade selection under natural light. The use of a smartphone with a flash produced a significantly different perception of tooth shade compared to that without flash. This could be due to the disruption of hue, chroma, and value introduced by artificial lighting and glare in the presence of flashlights. Thus, compromising the precise perception of shade. This finding is in line with the previous study by Fayed *et al*., who pointed out that the use of smartphone flashlight is not suitable for image acquisition during shade selection.[12] Moreover, Gómez-Polo *et al*. observed significant differences between the digital and visual methods of tooth shade selection.[13]

**Table 3:** Comparison of shade selection (A3) across different groups

| Groups | A3 | | Others | | $\chi^2$ | df | *P* |
|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | | | |
| With flash | 4 | 5.6 | 98 | 41.7 | 65.620 | 2 | <0.001 |
| Without flash | 16 | 22.5 | 86 | 36.6 | | | |
| Control | 51 | 71.8 | 51 | 21.7 | | | |
| Total | 71 | 100.0 | 235 | 100.0 | | | |

**Table 4:** Shade selection between A3 and other shades with and without use of flash

| Groups | A3 | | Others | | $\chi^2$ | df | *P* |
|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | | | |
| With flash | 4 | 20.0% | 98 | 53.3% | 7.983 | 1 | 0.005 |
| Without flash | 16 | 80.0% | 86 | 46.7% | | | |
| Total | 20 | 100.0% | 184 | 100.0% | | | |

Previous studies have reported significant differences in tooth shade selection among observers due to variations in lighting, color perception, and eye strain. These constitute subjective errors in the field of restorative and cosmetic dentistry, wherein precise color matching is required to obtain esthetic results.[3] In contrast, digital shade matching devices are objective and expensive requiring training and calibration.[14,15] This study highlights the important role of environmental control in the use of technology for shade selection.

The present study suggests that despite the benefits offered by the smartphones in tooth shade selection, its use should be supplementary until imaging and calibration protocols are developed. The study findings favour inclusion of Smartphone technology in shade selection teaching of the dental students to familiarize cost effective alternatives, specifically in conditions of a lack of Spectrophotometers. Smartphone without flash can be a supplemental method to visual inspection of the tooth shade selection. Future research should explore the effect of clinical atmosphere on standardized protocols on large samples.

**Table 5:** Shade selection methods and participants clinical years of training

| Shade | With flash | | | | | | Without flash | | | | | | Control | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6th Year | | 5th Year | | Interns | | 6th Year | | 5th Year | | Interns | | 6th Year | | 5th Year | | Interns | |
| | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| A3 | 1 | 2.9 | 2 | 5.9 | 1 | 2.9 | 7 | 20.6 | 4 | 11.8 | 5 | 14.7 | 19 | 55.9 | 16 | 47.1 | 16 | 47.1 |
| A2 | 0 | 0 | 0 | 0 | 1 | 2.9 | 3 | 8.8 | 3 | 8.8 | 2 | 5.9 | 4 | 11.8 | 4 | 11.8 | 1 | 2.9 |
| A3.5 | 3 | 8.8 | 4 | 11.8 | 3 | 8.8 | 3 | 8.8 | 10 | 29.4 | 9 | 26.5 | 0 | 0 | 1 | 2.9 | 2 | 5.9 |
| A4 | 7 | 20.6 | 3 | 8.8 | 7 | 20.6 | 2 | 5.9 | 2 | 5.9 | 4 | 11.8 | 0 | 0 | 0 | 0 | 1 | 2.9 |
| B2 | 0 | 0 | 1 | 2.9 | 1 | 2.9 | 0 | 0 | 0 | 0 | 1 | 2.9 | 0 | 0 | 0 | 0 | 1 | 2.9 |
| B3 | 3 | 8.8 | 3 | 8.8 | 5 | 14.7 | 6 | 17.6 | 7 | 20.6 | 7 | 20.6 | 3 | 8.8 | 7 | 20.6 | 3 | 8.8 |
| B4 | 4 | 11.8 | 5 | 14.7 | 9 | 26.5 | 7 | 20.6 | 4 | 11.8 | 3 | 8.8 | 0 | 0 | 0 | 0 | 2 | 5.9 |
| C2 | 0 | 0 | 1 | 2.9 | 2 | 5.9 | 2 | 5.9 | 1 | 2.9 | 0 | 0 | 4 | 11.8 | 2 | 5.9 | 2 | 5.9 |
| C3 | 3 | 8.8 | 4 | 11.8 | 0 | 0 | 1 | 2.9 | 2 | 5.9 | 1 | 2.9 | 2 | 5.9 | 1 | 2.9 | 1 | 2.9 |
| C4 | 5 | 14.7 | 6 | 17.6 | 2 | 5.9 | 0 | 0 | 0 | 0 | 1 | 2.9 | 0 | 0 | 0 | 0 | 2 | 5.9 |
| D2 | 1 | 2.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D3 | 3 | 8.8 | 1 | 2.9 | 3 | 8.8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2.9 | 3 | 8.8 | 2 | 5.9 |
| D4 | 4 | 11.8 | 4 | 11.8 | 0 | 0 | 3 | 8.8 | 1 | 2.9 | 1 | 2.9 | 1 | 2.9 | 0 | 0 | 1 | 2.9 |

**Table 6:** Comparison of A3 shade selection across different clinical year participants

| Years | With flash | | | | Without flash | | | | Visual method | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A3 | | Others | | A3 | | Others | | A3 | | Others | |
| | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| 6th year | 1 | 2.9 | 33 | 97.1 | 7 | 20.6 | 27 | 79.4 | 19 | 55.9 | 15 | 44.1 |
| 5th year | 2 | 5.9 | 32 | 94.1 | 4 | 11.8 | 30 | 88.2 | 16 | 47.1 | 18 | 52.9 |
| Interns | 1 | 2.9 | 33 | 97.1 | 5 | 14.7 | 29 | 85.3 | 16 | 47.1 | 18 | 52.9 |
| $\chi^2$ | 0.520 | | | | 1.038 | | | | 0.706 | | | |
| Df | 2 | | | | 2 | | | | 2 | | | |
| *P* | 1 | | | | 0.595 | | | | 0.703 | | | |

### Study limitations

This study solely relied on shade tab matching. Therefore, future research should include both shade tab matching natural dentition and other shade-measurement devices. The findings of this study cannot be generalized because of its focus on female students with limited clinical experience.

## CONCLUSION

Conventional method of visual shade selection is more reliable than smartphone-based methods. While smartphone photographs taken without flash may eventually find a place in clinical settings, it is essential to establish standardized protocols to ensure consistent and accurate shade matching.

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## REGISTRATION

This study is registered in research and innovation center of Riyadh Elm University, Riyadh, Saudi Arabia with the IRB Number (FUGRP/2025/410/1226/1113).

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