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# Assessing The Effectiveness of Shade Matching Using Visual Technique And Smartphone Application

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***Abstract***

***Aim:*** *The study aimed to assess and compare the effectiveness of shade matching using visual method and a smartphone application in tooth shade matching.*

***Materials and Methods:*** *A comparative observational study was conducted to evaluate the shade matching accuracy of the Colorimeter - Color Analysis smart phone application versus the conventional visual method. A total of 76 participants requiring shade matching for dental procedures were selected based on predetermined inclusion and exclusion criteria. Shade matching with visual method was done by three observers and data was recorded. Shade matching using Colorimeter – Color Analysis app was done by matching the L, a, and b values with predetermined L, a, and b values of the Vita Classical shade guide. The two sets of results were then compiled for comparison to assess the correlation and agreement between the two shade-matching methods. The statistical analysis was performed and Fleiss' Kappa & Cronbach's Alpha were applied for Inter-observer Reliability Analysis and individual shade matching. Cohen's Kappa was applied for intra-observer Reliability Analysis. The intraclass correlation test was employed to evaluate the accuracy of shade matching between observers across both techniques. A p-value of less than 0.05 was regarded as statistically significant.*

***Results:*** *The results showed that Inter-Observer reliability among observers for Conventional Method (Kappa value 0.888, Cronbach's Alpha – 0.926) and App Method (Kappa value 0.845, Cronbach's Alpha – 0.939) was high; and Intraclass correlation for shade matching between Conventional method (0.806) and App method (0.837) showed significant results.*

***Conclusion:*** *Smartphone application Colorimeter – Color Analysis can be used as an alternative to visual method for shade matching.*

***Keywords***: *Shade matching, Smartphone application, Colorimeter, Vita Classical*

## INTRODUCTION:

Precise matching of dental shade is a critical component in achieving visually harmonious and anatomically accurate prosthetic restorations. Conventionally, the use of visual assessment techniques employing shade guides has served as the primary method for determining tooth color. However, this approach is inherently subjective, resulting in potential variances due to non-standardized illumination conditions, discrepancies in individual perceptual acuity, and observer fatigue. Additional factors such as

the phenomenon of metamerism, insufficient calibration of shade guides, and human error further exacerbate the challenges associated with achieving consistent and reliable shade matching.[1]
To address these limitations, digital shade-matching technologies, such as spectrophotometers, colorimeters, and sophisticated imaging systems, have been developed. However, the high cost and limited accessibility of these devices restrict their widespread adoption in routine clinical practice. Recent advancements in smartphone technology have facilitated the emergence of mobile applications as viable alternatives for shade determination. These applications leverage digital colour analysis algorithms to evaluate shades based on established colorimetric models, such as the CIELAB system, which quantifies colour attributes numerically to improve precision and consistency in shade matching.[2]
Certain smartphone applications provide an economical and practical solution for shade matching by generating L*a*b* values, enabling clinicians to perform more objective and quantifiable shade evaluations. Additionally, these applications possess the capability to identify minute shade discrepancies within individual teeth. Under standardized lighting conditions, smartphone cameras can function as dependable instruments for shade determination, potentially enhancing both the precision and efficiency of the shade matching process.[1,3]
This study aimed to evaluate and compare the effectiveness of shade matching using a smartphone application against the visual method. With this the efficacy of mobile technology in dental shade determination is assessed, exploring the potential of smartphone-based applications as feasible alternatives to conventional methods. The research focuses on their capacity to enhance the accuracy and reproducibility of shade matching in restorative dentistry.[1]

## METHODOLOGY:

The study was conducted at the Department of Prosthodontics and Crown & Bridge, Sankalchand Patel University, Visnagar. After obtaining the ethical clearance, the study was conducted from June 2025 to July 2025. This study was designed to evaluate the shade matching efficiency of the conventional visual method using the Vita Classical shade guide and the smartphone application Colorimeter – Color Analysis. The objective was to assess whether the smartphone application can be used as an alternative to the conventional method for shade matching in clinical settings.

### Inclusion Criteria

Participants with natural, unrestored maxillary anterior teeth, no history of tooth bleaching or discoloration, and aged between 18 to 50 years were included in the study.

### Exclusion Criteria

Participants with intrinsic stains, restorations, or prostheses in anterior teeth, having color vision deficiencies, and with a history of systemic conditions affecting tooth color were excluded from the study.

### Sample size calculation

The sample size for the study was calculated using a priori power analysis based on the bivariate normal model for correlation analysis. The calculation was performed using statistical software G*Power (version 3.1.9.7). Based on the parameters, the software determined that a total sample size of **76 participants** would be sufficient to achieve the desired power, with an actual computed power of **0.8042**. This sample size ensures adequate sensitivity for detecting meaningful correlations in shade-matching accuracy between the conventional and smartphone-based methods.

### Procedure

A total of 76 subjects were enrolled in the study based on the predefined inclusion and exclusion criteria. To ensure accurate shade evaluation, professional dental prophylaxis was performed in the anterior region (canine to canine) to remove extrinsic stains and debris. Shade matching was carried out using two methods

- Conventional visual method using Vita Classical shade guide
- Smartphone application Colorimeter – Color Analysis

Three postgraduate students from the Department of Prosthodontics and Crown & Bridge, each having at least two years of experience in shade matching, were selected as observers. The observers did not know which shade their counterparts had chosen in either method of shade matching and were blinded accordingly to eliminate observer bias. Shade matching was performed independently for both methods. The Colorimeter – Color Analysis smartphone application (version 2.25.12 by Lab Tools) and a Samsung S23 FE smartphone camera (64 megapixels) were used alongside the Vita Classical shade guide to determine the Lightness (L), red/green (a), and blue/yellow (b) values of individual shade tabs in a controlled environment. A grey solid background and natural noon lighting were used for optimization. Each shade tab was positioned within the camera frame until the app's central marker aligned with the middle-third of the tab. Once stabilized, the corresponding L, a, and b values were displayed at the bottom of the application window. These readings were recorded for each shade tab.

Observers received a chart listing the predetermined L, a, and b values of individual shade tabs as seen in **Table 1**. Under the same optimized conditions as the visual method, observers matched the L, a, and b values of the tooth, determined via the Colorimeter – Color Analysis smartphone application, to the predefined values for each shade tab to select the appropriate shade.

**Fig. 1** – Armamentarium used – Grey solid background, Samsung Galaxy S23 FE, Vita Classical shade guide, Mobile tripod

| **Individual shade tab values** | | | |
|---|---|---|---|
| **Shade** | **L** | **a** | **b** |
| A1 | 91.3 | -0.4 | 2.3 |
| A2 | 80.6 | -0.2 | 12.4 |
| A3 | 83.6 | 0.8 | 10.3 |
| A3.5 | 78.2 | 0.4 | 10.6 |
| A4 | 76.5 | 1 | 11.2 |
| B1 | 90.6 | -0.2 | 3.8 |
| B2 | 85.1 | -0.7 | 13.6 |
| B3 | 82.2 | 0.7 | 13.2 |
| B4 | 81.2 | 1.3 | 12.5 |
| C1 | 90 | -0.3 | 8.7 |
| C2 | 88.3 | 1.7 | 12.3 |
| C3 | 84.6 | -0.2 | 12.1 |
| C4 | 79.2 | 1.5 | 11.5 |
| D2 | 89.7 | 0.9 | 10.1 |
| D3 | 85.6 | 1.1 | 13.3 |
| D4 | 77.5 | 1.2 | 14.5 |

**Table 1** - Individual shade tab values using Colorimeter – Color Analysis Application L-lightness; a-red/green value; b-blue/yellow value


**Fig. 2** – L, a, and b values of individual shade tab from Vita Classical shade guide using Colorimeter – Color Analysis


**Fig. 3** – L, a, and b values of selected tooth matched with predetermined L, a, and b values of individual shade tab from Vita Classical shade guide using Colorimeter – Color Analysis

In the visual shade matching method, the patient was positioned upright on a dental chair. Observers assessed the shade of the upper central incisor from a standardized eye distance of 25 cm. Each observer evaluated 76 subjects, and the selected shades were systematically recorded. The shade matching was done under natural daylight conditions, when ambient light is stable and neutral. It provides a colour temperature of about 5500 K, closely representing the standard for shade matching recommended in dental literature. Operatory lights were turned off to avoid interference from artificial light sources. A neutral grey background was employed during shade matching.

In the smartphone-assisted shade matching method using Colorimeter – Color Analysis, the application's alignment marker was positioned to correspond with the central region of the middle-third of the tooth. In this study, a standardized camera-to-shade tab distance of 25 cm was maintained to optimize environmental conditions. While controlled lighting parameters were applied in this research, clinical settings often exhibit variability in illumination, making it impractical to establish uniform shade values across all scenarios. Fluctuations in lighting inherently affect the precise chromatic attributes of individual shade tabs.

456 shade samples were obtained from 76 subjects. The two sets of results were then compiled for comparison to assess the correlation and agreement between the two shade-matching methods as in **Table 2** and **Table 3**.

| Patient number | Observer 1 | Observer 2 | Observer 3 |
|---|---|---|---|
| 1 | A1 | B1 | A1 |
| 2 | A3 | A3 | A3 |
| 3 | A1 | A1 | A1 |
| 4 | B1 | B1 | B1 |
| 5 | A2 | A2 | A2 |
| 6 | A2 | A2 | A2 |
| 7 | A2 | A2 | A2 |
| 8 | A1 | A1 | A1 |
| 9 | B1 | B1 | B1 |
| 10 | A3.5 | A3 | A3 |
| 11 | A2 | A2 | A2 |
| 12 | A1 | A1 | A1 |
| 13 | A2 | A2 | A2 |
| 14 | B2 | B2 | B2 |
| 15 | A1 | A1 | C1 |
| 16 | B1 | B1 | B1 |
| 17 | A1 | A1 | A1 |
| 18 | A2 | A2 | A2 |
| 19 | A1 | A1 | A1 |
| 20 | A2 | A2 | A2 |
| 21 | A2 | A2 | A2 |
| 22 | A3.5 | A3 | A3.5 |
| 23 | A1 | A1 | A1 |
| 24 | A2 | A2 | A2 |
| 25 | A1 | A1 | B1 |
| 26 | A1 | A1 | A1 |
| 27 | B2 | B2 | B2 |
| 28 | A2 | A2 | A2 |
| 29 | C1 | C1 | B1 |
| 30 | A3 | A3 | A3 |
| 31 | B2 | B2 | B2 |
| 32 | A2 | A2 | A2 |
| 33 | A2 | A2 | A2 |
| 34 | A3 | A3 | A3 |
| 35 | A1 | A1 | A1 |
| 36 | B1 | B1 | B1 |
| 37 | A2 | A2 | A2 |
| 38 | B2 | B2 | B2 |
| 39 | A1 | A1 | A1 |
| 40 | A2 | A2 | A2 |
| 41 | A1 | A1 | A1 |
| 42 | A3 | A3 | A3 |
| 43 | A3.5 | A3.5 | A3.5 |
| 44 | B1 | B1 | B1 |
| 45 | A2 | A2 | A2 |

| | | | |
|---|---|---|---|
| 46 | B1 | C1 | B1 |
| 47 | A1 | B1 | B1 |
| 48 | A2 | A2 | A2 |
| 49 | A1 | A1 | A1 |
| 50 | B1 | B1 | B1 |
| 51 | C1 | C1 | C1 |
| 52 | A2 | A2 | A2 |
| 53 | A1 | A1 | A1 |
| 54 | B1 | B1 | B1 |
| 55 | A3.5 | A3.5 | A3.5 |
| 56 | A1 | A1 | A1 |
| 57 | A2 | A2 | A2 |
| 58 | A2 | A2 | A2 |
| 59 | A1 | A1 | A1 |
| 60 | B2 | A2 | A2 |
| 61 | B1 | B1 | B1 |
| 62 | B1 | B1 | B1 |
| 63 | A2 | A2 | A2 |
| 64 | A1 | A1 | A1 |
| 65 | C1 | C1 | C1 |
| 66 | A2 | A2 | A2 |
| 67 | A1 | A1 | A1 |
| 68 | A1 | A1 | A1 |
| 69 | A3 | A3 | A3 |
| 70 | A2 | B2 | A2 |
| 71 | B1 | B1 | B1 |
| 72 | A1 | A1 | A1 |
| 73 | B1 | B1 | B1 |
| 74 | A3 | A3 | A3 |
| 75 | B1 | B1 | B1 |
| 76 | A2 | A2 | A2 |

**Table 2** - Shade matching using visual technique by three observers for 76 subjects

| Patient number | Observer 1 | Observer 2 | Observer 3 |
|---|---|---|---|
| 1 | A1 | A1 | A1 |
| 2 | A3 | A3 | A3 |
| 3 | A1 | A1 | A1 |
| 4 | B1 | B1 | B1 |
| 5 | B2 | A2 | A2 |
| 6 | A2 | A2 | A2 |
| 7 | A2 | A2 | A2 |
| 8 | A1 | A1 | A1 |
| 9 | B1 | B1 | B1 |
| 10 | A3 | A3 | A3 |
| 11 | A2 | B2 | B2 |
| 12 | A1 | A1 | A1 |
| 13 | A2 | A2 | A2 |

| | | | |
|---|---|---|---|
| 14 | B2 | B2 | B2 |
| 15 | A1 | A1 | A1 |
| 16 | B1 | B1 | B1 |
| 17 | A1 | A1 | A1 |
| 18 | B2 | A2 | B2 |
| 19 | A1 | A1 | A1 |
| 20 | A2 | A2 | A2 |
| 21 | A2 | A2 | A2 |
| 22 | A3 | A3 | A3.5 |
| 23 | A1 | A1 | A1 |
| 24 | A2 | A2 | A2 |
| 25 | A1 | A1 | A1 |
| 26 | A1 | A1 | A1 |
| 27 | B2 | B2 | B2 |
| 28 | A2 | A2 | B2 |
| 29 | C1 | C1 | C1 |
| 30 | A3 | A3 | A3 |
| 31 | B2 | B2 | B2 |
| 32 | A2 | A2 | A2 |
| 33 | A2 | A2 | A2 |
| 34 | A3 | A3 | A3 |
| 35 | B1 | B1 | A1 |
| 36 | B1 | B1 | B1 |
| 37 | A2 | A2 | A2 |
| 38 | B3 | B3 | B2 |
| 39 | A1 | A1 | A1 |
| 40 | A2 | A2 | A2 |
| 41 | A1 | A1 | A1 |
| 42 | A3 | A3 | A3 |
| 43 | A3.5 | A3.5 | A3.5 |
| 44 | B1 | B1 | B1 |
| 45 | A2 | B2 | A2 |
| 46 | B1 | C1 | B1 |
| 47 | A1 | B1 | B1 |
| 48 | A2 | A2 | A2 |
| 49 | A1 | A1 | A1 |
| 50 | B1 | B1 | B1 |
| 51 | C1 | C1 | C1 |
| 52 | A2 | A2 | A2 |
| 53 | A1 | A1 | A1 |
| 54 | B1 | B1 | B1 |
| 55 | A3.5 | A3.5 | A3.5 |
| 56 | A1 | A1 | A1 |
| 57 | A2 | A2 | A2 |
| 58 | A2 | A2 | A2 |
| 59 | A1 | A1 | A1 |
| 60 | B2 | A2 | A2 |

| | | | |
|---|---|---|---|
| 61 | B1 | B1 | B1 |
| 62 | A1 | A1 | B1 |
| 63 | A2 | A2 | A2 |
| 64 | A1 | A1 | A1 |
| 65 | C1 | C1 | C1 |
| 66 | A2 | A2 | A2 |
| 67 | A1 | A1 | A1 |
| 68 | A1 | A1 | A1 |
| 69 | A3 | A3 | A3 |
| 70 | A2 | B2 | B2 |
| 71 | B1 | B1 | B1 |
| 72 | A1 | A1 | A1 |
| 73 | B1 | B1 | B1 |
| 74 | A3 | A3 | A3 |
| 75 | B1 | A1 | A1 |
| 76 | A2 | A2 | A2 |

**Table 3** - Shade matching using Colorimeter – Color Analysis App by three observers for 76 subjects

**Statistical Analysis:**

The statistical analysis was performed using International Business Management (IBM) Statistical Package for Social Sciences (SPSS) statistics for Windows, version 26.0 (IBM Corp, Armonk, New York, USA). Fleiss' Kappa was applied for Inter-observer Reliability Analysis and individual shade matching. Cohen's Kappa was applied for intra-observer Reliability Analysis. The p-value of $< 0.05$ was considered statistically significant. Along with the above-mentioned tests, Cronbach's Alpha statistical test was utilized to assess interobserver reliability. The intraclass correlation test was employed to evaluate the accuracy of shade matching between observers across both techniques. Additionally, the Spearman rho correlation test was used to analyse the observations recorded by individual observers for each technique. A p-value of less than 0.05 was regarded as statistically significant.

**RESULTS:**

Two groups, Group A and Group B, based on methods of shade matching, consisted of 76 subjects each. Three observers were selected for shade matching. As mentioned in **Table 4** and **Table 5** - Assessment of Inter-Observer Reliability analysis for shade matching was done using Fleiss' Kappa and Cronbach's Alpha tests. Fleiss' Kappa Analysis for the Conventional method was 0.888, and for the App method was 0.845, respectively. This revealed that there is strong agreement between the observers in both techniques. Cronbach's Alpha Analysis for the Conventional method was 0.939, and for the App method was 0.926, respectively. This revealed that there is excellent consistency between the observers in both techniques. **Table 6** shows Intra-rater reliability of Observer 1 for both techniques had a Kappa value of 0.883, Observer 2 for both techniques had a Kappa value of 0.884, and Observer 3 for both techniques had a Kappa value was 0.867. A high Kappa value indicates strong (almost perfect) Intra-rater reliability, suggesting that the observer is making consistent judgments. As seen in **Table 7**, Intraclass correlation test for the Conventional method was 0.806, and for the App method was 0.837, respectively. In both techniques, results were highly significant ($p \leq 0.001$). This suggests substantial agreement among the observers in both techniques. **Table 8** shows Agreement on individual shade matching with the Conventional method. It had Kappa values for A1 (0.910), A2 (0.959), A3 (0.895), A3.5 (0.769), B1 (0.857), B2 (0.848), and C1 (0.686). These individual Kappa values indicate that observers are in very good agreement when shade matching is done as A1, A2, A3, B1, and B2, while good agreement is observed when shade matching is done as A3.5 and C1. **Table 9** shows Agreement on individual shade matching with the App method. It had Kappa values for A1 (0.915), A2 (0.845), A3 (0.952), A3.5 (0.853), B1 (0.842), B2 (0.562), B3 (0.496), and C1 (0.895). These individual Kappa values indicate that observers are in very good agreement when shade matching is done as A1, A2, A3, A3.5, B1, and C1, while moderate agreement when shade matching is done as B2 and B3.

| Method | Kappa | P value |
|---|---|---|
| Conventional Method | 0.888 | <0.001 |
| App Method | 0.845 | <0.001 |

**Table 4** - Inter-Observer reliability among observers for Conventional Method and App Method

| Method | Cronbach's alpha | P value |
|---|---|---|
| Conventional Method | 0.926 | <0.001 |
| App Method | 0.939 | <0.001 |

**Table 5** - Inter-Observer reliability among observers for Conventional Method and App Method

| Observer | Kappa | P value |
|---|---|---|
| 1 | 0.883 | <0.001 |
| 2 | 0.884 | <0.001 |
| 3 | 0.867 | <0.001 |

**Table 6** - Intra-rater reliability of an observer

| Method | Intraclass correlation | P value |
|---|---|---|
| Conventional Method | 0.806 | <0.001 |
| App Method | 0.837 | <0.001 |

**Table 7** - Intraclass correlation for shade matching

| Shade Matching | Kappa | P value |
|---|---|---|
| A1 | 0.910 | <0.001 |
| A2 | 0.959 | <0.001 |
| A3 | 0.895 | <0.001 |
| A3.5 | 0.769 | <0.001 |
| B1 | 0.857 | <0.001 |
| B2 | 0.848 | <0.001 |
| C1 | 0.686 | <0.001 |

**Table 8** - Agreement on individual Shade matching for Conventional Method

| Shade Matching | Kappa | P value |
|---|---|---|
| A1 | 0.915 | <0.001 |
| A2 | 0.845 | <0.001 |
| A3 | 0.952 | <0.001 |
| A3.5 | 0.853 | <0.001 |
| B1 | 0.842 | <0.001 |
| B2 | 0.562 | <0.001 |
| B3 | 0.496 | <0.001 |
| C1 | 0.895 | <0.001 |

**Table 9** - Agreement on individual Shade matching for App Method

**DISCUSSION:**

The colour we perceive in an object is not an inherent trait of the object itself but rather the result of light interacting with its surface and entering our eyes. In the case of teeth, what we refer to as "tooth colour" is the specific wavelength of light reflected from the surface of the tooth and interpreted by the brain through our visual system. This perception is significantly influenced by the surrounding light conditions and the way our eyes process visual information. The retina plays a vital role in this process; it's a complex, light-sensitive layer at the back of the eye, containing two primary types of photoreceptor cells: rods and cones. While rods are responsible for vision in dim light, cones are specialized for detecting colour under brighter lighting conditions. The human eye, when fully engaged with ample illumination, is capable of distinguishing up to approximately 300 unique spectral hues. This incredible sensitivity enables subtle colour differences to be detected, but it also introduces challenges.[4]

In the field of aesthetic dentistry, shade matching is far more than a technical skill; it's an art that demands exceptional visual acuity, sustained focus, and a deep understanding of color dynamics. Replicating the natural appearance of a tooth, including its shade, translucency, texture, and how it interacts with ambient light, requires not only tools and techniques but also experience and intuition. Despite the routine nature of color communication in dental practice, misunderstandings are common. Shade matching combines both subjective (visual) and objective (scientific) elements, and no two individuals perceive color in the same way. Factors such as eye fatigue, lighting conditions, surrounding colors, and even emotional state can influence a dentist's perception of shade.[5,6]

According to Fondriest J et al. (2003), when the retina is exposed to light for a period and the light source is suddenly removed, the visual receptors in the eye remain momentarily active, continuing to send signals to the brain. This lingering activity, known as the spreading effect, can lead to a temporary shift in perception. This shift is a result of an "after image" - a normal physiological response of the eye's receptors. When cone cells in particular become overstimulated and fatigued, they may become less responsive, producing what's called a negative afterimage. In the context of dental shade matching, this phenomenon emphasizes the importance of making a colour match decision quickly within a few seconds, before visual fatigue alters perception.[7]

In addition to the physical characteristics of the tooth itself, a clinician's ability to distinguish subtle differences in hue, chroma, and value plays a critical role in accurate shade matching. Because this process relies heavily on the individual's visual perception, even slight inconsistencies can result in restorations that clash with the patient's natural teeth and compromise aesthetics.[8] In such scenarios, incorporating supportive tools like smartphone apps designed for shade analysis can be highly beneficial. These digital aids enhance the precision of shade matching, which is a fundamental prerequisite for delivering a prosthesis that blends seamlessly and looks natural.[9]

Albert CJ et al. (2019) explored the use of smartphone technology in evaluating the color of dental prostheses. Their objective was to simplify the shade selection process for clinicians by utilizing photographs captured with smartphones. For this, they employed the VITA 3D MASTER shade guide to assess color based on images of individual teeth. The study found that while this approach serves as a supplement rather than a replacement for traditional shade matching techniques, it significantly reduces the chances of error during the selection process.[10] Mohammadi A et al. (2021) focused on testing the accuracy and consistency of shade determination through smartphone photography. The study used two smartphone-based applications along with Adobe Photoshop to assess shades from the Vita Lumin Vacuum and 26 tabs of the VITA 3D MASTER shade system. The results highlighted that when smartphone images are properly calibrated and analysed through software like Adobe Photoshop, the method demonstrates high levels of validity and reliability.[11] In another investigation, Raza F et al. (2021) carried out a prospective clinical study to evaluate the dependability of software-based tools in selecting natural tooth shades and concluded that software applications were reliable for shade matching.[12]

The conclusion drawn from this research emphasized that digital applications not only offer consistent results but also ensure repeatability, making them reliable assets in clinical shade matching procedures. In the current study, the Kappa value determined by Fleiss' Kappa Analysis for the Conventional method was 0.888, and for the App method was 0.845, respectively. This revealed that there is strong agreement between the observers in both techniques. Intra-rater reliability of Observer 1 for both techniques had a Kappa value of 0.883, Observer 2 for both techniques had a Kappa value of 0.884, and Observer 3 for both techniques had a Kappa value was 0.867. A high Kappa value indicates strong (almost perfect) Intra- rater reliability, suggesting that the observer is making consistent judgments. The findings from the study aligned with earlier research, reinforcing that using smartphone applications for shade matching is a dependable and supportive tool alongside traditional visual methods involving shade tabs. This approach proves especially useful in cases where a clinician experiences visual fatigue, diminished ability to distinguish subtle shade differences, or works under artificial lighting conditions.[13] However, for the method to be effective, the shade tab values must be calibrated and recorded within the same lighting environment in which they're being used. Camera settings, type of smartphone camera, the neutral grey background used, and the light settings may alter the results obtained in the present study.

## CONCLUSION:

Within the limitations of the current study, although traditional visual techniques remain the most dependable approach for selecting dental shades, incorporating smartphone-based tools like Colorimeter – Color Analysis can offer added value in clinical settings. These digital technologies help bring more objectivity to the process, allow for easy documentation, and can serve as practical references during both treatment planning and communication with dental labs. Still, before they can be fully embraced as standard practice, there's a need for continued innovation in app development and confirmation of their effectiveness through broader, well-designed clinical studies.

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