International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 6, 2025
https://theaspd.com/index.php

# "Comparative Evaluation of Shade Matching Accuracy: Smartphone Application Vs. Conventional Visual Method"

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***Abstract:***

***Aim:*** *To compare the shade-matching accuracy between a smartphone application (NAiBU) and the conventional visual method using the Vita Classic shade guide in dental shade selection.*

***Methods:*** *A total of 76 subjects were selected. Shade matching was performed on natural, unrestored maxillary anterior teeth using both the Vita Classic shade guide (conventional method) and the NAiBU smartphone application in Google pixel 8a with 64 MP (upto 8x Digital Zoom) wide angle primary camera specifications. Standardized conditions were maintained throughout, including the use of cheek retractors and consistent natural lighting. Shade tabs were positioned at a distance of 25 cm against a neutral grey background for visual matching. The selected shades were recorded and tabulated. Data were subjected to statistical analysis using Cronbach's alpha for interobserver reliability, intraclass correlation coefficient (ICC) for assessing consistency among observers, and Spearman's rho test to evaluate intra-observer correlation between the two methods.*

***Results:*** *Interobserver reliability was higher for the conventional technique (Cronbach's alpha = 0.60) compared to the app technique (0.047), indicating greater consistency among observers. Intraclass correlation also favored the conventional method (0.59,* $p \leq 0.001$*), while the app showed low agreement (0.04,* $p = 0.389$*). A statistically significant positive correlation was observed between the app and observer assessments (Spearman's* $\rho = 0.39$*,* $p = 0.001$*).*

***Conclusion:*** *Within the limitations of the study, it can be concluded that the NAiBU app demonstrates potential as a supplementary aid in tooth shade selection; however, it cannot yet replace the conventional visual method due to several inherent limitations. One of the primary challenges lies in the variability introduced by different mobile devices– each with distinct camera specifications, sensor quality, and color calibration.*

***Key words:*** *Ai tool, Mobile application, Shade guide, Shade selection, Smart phone,*

## INTRODUCTION:

Achieving a natural and aesthetically pleasing appearance is one of the primary objectives in restorative dentistry, particularly in anterior restorations where cosmetic outcomes are of utmost importance. Among the various factors that contribute to the success of dental restorations, accurate tooth shade selection

plays a pivotal role. Shade mismatches can lead to patient dissatisfaction, repeated clinical appointments, and increased laboratory work, thereby compromising the overall efficiency and outcome of treatment. [1] Traditionally, the conventional visual method using shade guides, such as the Vita Classical shade guide, has been the gold standard for selecting tooth shades. This method relies on the clinician's subjective perception of color, influenced by various factors including ambient lighting, individual color vision, viewing angle, and even the clinician's level of fatigue. [1] Furthermore, phenomena like metamerism— where colors appear differently under different lighting conditions—and the lack of standardization across different shade guide systems further complicate the shade-matching process. These limitations have necessitated the development of more objective and reliable methods for tooth shade selection. [1,2]

In recent years, technological advancements have introduced digital tools aimed at reducing human error in shade matching. Instruments such as spectrophotometers, colorimeters, and intraoral scanners with shade analysis capabilities have been developed to provide more consistent and reproducible results. However, these devices often come with high costs, limiting their accessibility in many dental practices. [2] To bridge this gap, smartphone-based applications have emerged as a promising alternative due to their affordability, ease of use, and accessibility. Applications like NAiBU and Color Grab utilize advanced image processing and artificial intelligence to assist clinicians in selecting tooth shades more objectively. These apps can provide CIELAB (Lab*) values, enabling precise color communication and documentation. Additionally, they can detect subtle intratooth shade variations, enhancing the ability to replicate the natural aesthetics of the dentition. [3]

However, despite their potential, smartphone applications are not without limitations. Factors such as variable lighting conditions, differences in smartphone camera quality, and lack of calibration protocols can impact the accuracy and reliability of digital shade matching. Thus, a comprehensive evaluation is necessary to determine whether these tools can serve as dependable alternatives or supplements to the conventional method. [1,3]

The present study aims to evaluate and compare the accuracy of shade matching using a smartphone application (NAiBU) versus the conventional visual method with a Vita Classic shade guide. By exploring the strengths and limitations of both approaches, this research seeks to contribute valuable insights into the integration of digital technology in routine dental practice, ultimately enhancing the precision and consistency of shade matching in restorative dentistry. [4]

## METHODOLOGY:

This study is a comparative observational study designed to evaluate the shade-matching accuracy of the NAiBU smartphone application versus the conventional visual method using the Vita Classic shade guide. The objective is to assess whether the smartphone-based application can serve as a reliable alternative to traditional shade selection methods in clinical settings.

The study was conducted at the Department of Prosthodontics and Crown & Bridge, Narsinhbhai Patel Dental College and Hospital. Participants visiting the department for dental treatment and meeting the selection criteria was included. Informed consent was taken from all participants involved in the study.

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

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

**Sample size calculation:** The sample size for this study was calculated using a priori power analysis based on the bivariate normal model for correlation analysis. The calculation was performed using statistical software, referencing the methodology described by Tumma SH et al. (2022).

Based on 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 predefined inclusion and exclusion criteria. Prior to participation, informed consent was obtained from all individuals. Only patients with good to fair oral hygiene, natural unrestored maxillary anterior teeth, and no crowding or prosthetic restorations were included. To ensure accurate shade evaluation, professional dental prophylaxis was performed in the anterior region (canine to canine) to remove extrinsic stains and debris.

Shade selection was carried out using two different techniques:

1. **Conventional Visual Method**
2. **Smartphone-Based NAiBU Application**

Three postgraduate students from the Department of Prosthodontics and Crown and Bridge, each with at least two years of experience in shade matching, were selected as observers. All observers were calibrated prior to the study and were blinded to each other's results to eliminate bias. They performed shade selection independently for both methods.

In the **conventional visual method**, all shade matching was conducted under **natural daylight conditions**, preferably during mid-morning hours (between 10:00 AM to 12:00 PM) when ambient light is stable and neutral. Natural daylight provides a color temperature of approximately 5500 Kelvin, closely representing the standard for shade selection recommended in dental literature. Clinical operatory lights were turned off during visual assessments to avoid interference from artificial light sources that may alter the perceived color of teeth or shade tabs.

To further minimize environmental influences, a **neutral gray background** was employed during shade matching. The use of a gray backdrop behind the patient's head serves to eliminate unwanted visual distractions and reflections caused by brightly colored clothing, which can affect color perception due to surrounding contrast and metamerism.

Fig.1 Observer 1

Fig.2 Observer 2

Fig.3 Observer 3

In **Smartphone-Based Method using NAiBU App,** photographs of the maxillary central incisor were captured using a Google pixel 8a with 64 MP (upto 8x Digital Zoom) wide angle primary camera. A standardized distance and angulation were maintained for all photographs. The app analyzed the tooth shade based on the image and provided the closest shade match. Observers recorded the app-generated shade without interference or guidance.

In the **smartphone-based method**, the NAiBU application was used to capture and analyze images of the maxillary anterior teeth. Photographs were taken under consistent lighting and distance settings to ensure standardization. The application processed the images and suggested the closest matching shade, which was documented for analysis.

Fig.4 Upload captured photographs in NAiBU

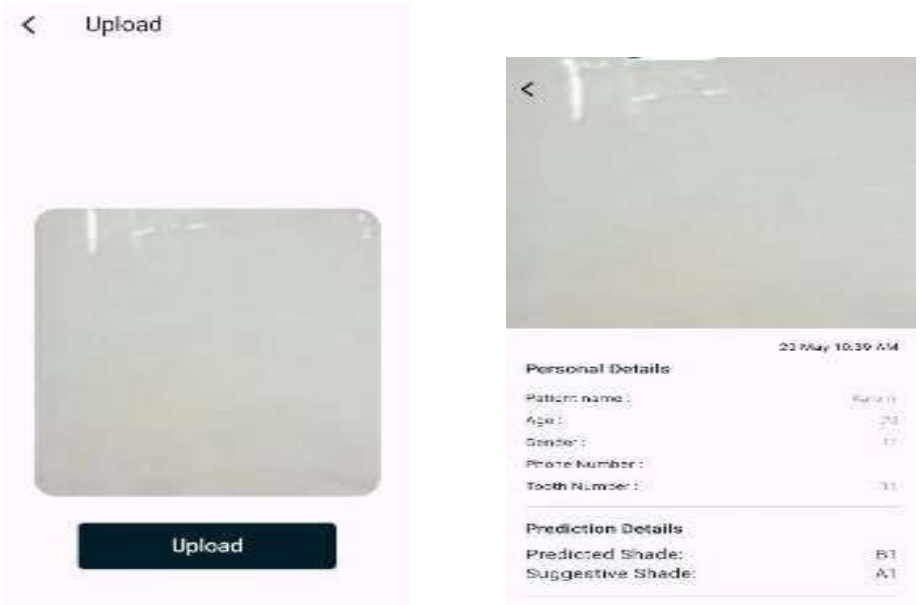


Fig.5 Considered suggested shade in NAiBU App

Both sets of results were then compiled for comparison to assess the correlation and agreement between the two shade-matching methods.

**Statistical Analysis**:
Statistical analysis was conducted using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). To assess the reliability of shade selection among the three observers, **Cronbach's alpha** was used for interobserver reliability analysis. **Intraclass correlation coefficient (ICC)** was applied to evaluate the agreement and consistency in shade selection between observers for both the conventional visual method and the NAiBU smartphone application. Additionally, **Spearman's rho correlation test** was utilized to analyze the relationship between the two techniques as recorded by individual observers. A **p- value of less than 0.05** was considered statistically significant for all tests.

**RESULTS:**
The findings of this study provide valuable insights into the reliability and agreement of shade selection using two different methods: the conventional Vita Classic shade guide and the NAiBU smartphone application. In **table 1** interobserver reliability, assessed using Cronbach's alpha, demonstrated a higher level of consistency among observers with the conventional technique ($\alpha$ = 0.60) compared to the app- based method ($\alpha$ = 0.047). The

conventional method displayed acceptable reliability, while the app technique indicated poor interobserver consistency. These results suggest that the traditional visual method remains more consistent among different observers in clinical settings.

**Table 1: Reliability analysis (interobserver) for shade selection**

| Technique | Cronbach's alpha |
|---|---|
| Conventional technique | 0.60 |
| App technique | 0.047 |

**Table 2: Intraclass correlation**

| Technique | Cronbach's alpha (Intraclass correlation) | p-value |
|---|---|---|
| Conventional technique | 0.59 | ≤ 0.001* |
| App technique | 0.04 | 0.389 |

In **table 2** intraclass correlation coefficient (ICC), which measures agreement within observer assessments, showed a similar trend. The conventional method yielded an ICC of 0.59 with a statistically significant p- value (≤ 0.001), indicating moderate agreement and reliability. In contrast, the app technique demonstrated a much lower ICC of 0.04, with a non-significant p-value (p = 0.389), suggesting negligible agreement within observers when using the mobile application. This further supports the notion that the conventional method provides a more reliable framework for consistent shade matching among clinicians.

**Table 3: Correlation**

| Spearman's rho | Correlation coefficient with app | p-value |
|---|---|---|
| Observers (Positive correlation) | 0.39 | 0.001* |

**Test applied: Spearman rho** ***p-value < 0.05 statistically significant**

Despite the lower reliability of the app-based technique, the Spearman's rho correlation test revealed a statistically significant positive correlation ($\rho = 0.39$, $p = 0.001$) between the shade selections made by the app and at least one of the observers using the conventional method. While this correlation is relatively weak, it suggests some degree of alignment between the two methods, particularly with specific observers. However, the overall low correlation values and interobserver inconsistency with the app indicate that its accuracy and reliability in clinical use may be limited without further refinement or training.

**DISCUSSION:**

Accurate shade selection is a critical component in achieving esthetic success in restorative dentistry. The visual perception of tooth color is a complex interaction of light, object, and the observer's visual system. [5] The human eye perceives the color of a tooth not as an inherent property, but as the light reflected from the tooth surface that stimulates the retina. The retina, composed of rods and cones, plays a central role in translating this light information into perceived color. [6,7] The ability to differentiate subtle spectral variations is heightened under adequate lighting, allowing for the perception of up to 300 distinct spectral colors. However, this process is highly subjective and prone to inconsistencies among observers, particularly under non- standardized conditions. [8,9] The challenge for clinicians lies not only in perceiving the correct shade but also in replicating it in restorative materials. Human perception is influenced by physiological phenomena such as the "spreading effect" and "after-image," as described by Fondriest. [10,11] These effects result from retinal fatigue, especially of cone receptors, which leads to temporary alterations in color perception. Such phenomena underscore the necessity of rapid and efficient shade matching when using visual methods, as prolonged observation can distort true color perception. Additionally, brunescence—the age-related browning of the cornea— further complicates perception by altering the appearance of colors due to a filtering effect. Hence, clinician- specific variables such as age, visual acuity, and fatigue may impact the accuracy of visual shade selection. [12,13]

Given the inherent limitations of human vision in dental color matching, alternative methods have emerged to support clinical decision-making. Digital tools such as smartphone applications present an opportunity to reduce subjectivity and improve standardization. [14,15] In this study, shade matching performed with the NAiBU smartphone application was compared to the conventional visual method using the Vita Classic shade guide. Results revealed that interobserver reliability, as assessed by Cronbach's alpha, was higher for the conventional method (0.60) compared to the NAiBU app (0.047), indicating moderate consistency among observers using the traditional approach and poor consistency with the app. Similarly, intraclass correlation analysis yielded stronger agreement within the conventional method group (ICC = 0.59, $p \leq 0.001$) than the app group (ICC = 0.04, $p = 0.389$), further supporting the superiority of visual matching in terms of consistency among observers. Despite this, the Spearman's rho test indicated a statistically significant positive correlation ($\rho = 0.39$, $p = 0.001$) between the shade selections made by the app and at least one observer using the conventional method. Although this correlation is weak, it suggests some alignment between the two techniques, particularly with certain observers. The observed variability among users may be attributed to factors such as differences in smartphone camera quality, lighting conditions, and calibration settings, which can influence image-based color perception and analysis.

Previous research supports the potential of smartphone-assisted shade selection as a complementary tool rather than a standalone replacement. Albert CJ et al. utilized smartphone photography with the VITA 3D MASTER shade guide and found that while the method did not replace conventional techniques, it served as a valuable adjunct that helped reduce potential errors in shade selection. [14,16] Similarly, Mohammadi A et al. demonstrated that high validity and reliability could be achieved using calibrated smartphone photography analyzed via Adobe Photoshop software. [15,17] These findings are corroborated by Raza F et al., whose clinical study confirmed the reliability and repeatability of mobile software applications in natural tooth shade selection. [18,19,20]

The NAiBU app shows promise as a supplementary tool for tooth shade selection; however, it currently cannot replace the conventional visual method due to notable limitations. A significant concern is the variability introduced by different mobile devices, each equipped with unique camera specifications, sensor qualities, and color rendering capabilities. These differences contribute to photographic inconsistencies that affect the accuracy and reliability of shade matching. As a result, while the app can serve as a helpful adjunct—particularly for documentation, patient engagement, or preliminary assessments—exclusive dependence on digital shade matching is not recommended until greater standardization and calibration across mobile platforms are achieved.

## CONCLUSION:

In conclusion, while conventional visual methods continue to demonstrate superior reliability in shade selection, the integration of smartphone applications such as NAiBU may provide supplemental value in clinical practice. These digital aids can enhance objectivity, offer documentation capabilities, and serve as useful references during treatment planning and laboratory communication. However, further advancements in app design and validation through larger-scale studies are essential before widespread adoption in clinical workflows can be recommended.

**Acknowledgments:**

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES:**

1) Hari TS, Thonse EP, Hallikerimath RB, Melavanki CL, Nayak AK, Ruttonji ZA. 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.
2) Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. Journal of dentistry. 2010 Jan 1;38: e2-16.
3) Gotfredsen K, Gram M, Ben Brahem E, Hosseini M, Petkov M, Sitorovic M. Effectiveness of shade measurements using a scanning and computer software system: a pilot study. Int J Oral Dent Health. 2015;1(008).
4) Nafea I, Alharbi A, Abduh A, Alharbi A, Moussa RM. Color shade matching by mobile applications in dental practice: An experimental comparative in-vitro double-blind study. The Saudi Dental Journal. 2019 Jan 1;31: S13.
5) Xiao K, Liao N, Zardawi F, Liu H, Noort RV, Yang Z, Huang M, Yates JM. Investigation of Chinese skin colour and appearance for skin colour reproduction. Chinese Optics Letters. 2012 Aug 1;10(8):083301.
6) Agrawal V, Kapoor S. Color and shade management in esthetic dentistry. Univers Res J Dent. 2013 Dec 1;3(3):120-7.
7) Khurana R, Tredwin CJ, Weisbloom M, Moles DR. A clinical evaluation of the individual repeatability of three commercially available colour measuring devices. British dental journal. 2007 Dec 22;203(12):675-80.
8) Gasparik C, Grecu AG, Culic B, Badea ME, Dudea D. Shade-matching performance using a new light-correcting device. Journal of Esthetic and Restorative Dentistry. 2015 Sep;27(5):285-92.
9) Sato RR, Shiraishi A, Ishibashi K. Using a computer color-matching system. A newly developed spectrophotometer designed for clinical application. Int J Prosthodont. 1994; 7:50-8.
10) Fondriest J. Shade matching in restorative dentistry: the science and strategies. International Journal of Periodontics and Restorative Dentistry. 2003 Oct 1;23(5):467-80.
11) Fondriest J. Shade matching in restorative dentistry: the science and strategies. J. Prosthet. Dent. 2004 Jun 1;91(6):553.
12) Pensler AV. Shade selection: problems and solutions. Compendium of Continuing Education in Dentistry (Jamesburg, NJ: 1995). 1998 Apr 1;19(4):387-90.
13) Tam WK, Lee HJ. Accurate shade image matching by using a smartphone camera. Journal of prosthodontic research. 2017;61(2):168-76.
14) Albert CJ, Da Silva EN, Penteado MM, de LIMA DR, Kimpara ET, Uemura ES. Color assessment in dental prostheses: the use of smartphones as process tools. Brazilian Dental Science. 2019 Oct 31;22(4):573-7.
15) Mohammadi A, Bakhtiari Z, Mighani F, Bakhtiari F. Validity and reliability of tooth color selection by smartphone photography and software applications. The Journal of Indian Prosthodontic Society. 2021 Jul 1;21(3):281-6.
16) 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 International. 2021 Jul 1;52(7).
17) Jain S, Angural V. Use of Cronbach's alpha in dental research. Medico Research Chronicles. 2017;4(3):285-91.
18) Mina RK. Comparing Traditional and Digital Shade Selection in Dentistry: A Review of Literature. Egyptian Dental Journal. 2025 Jan 1;71(1):703-10.
19) Nayak VM, Sulaya K, Venkatesh SB. Current trends in digital shade matching–A scoping review. Japanese Dental Science Review. 2024 Dec 1;60: 211-9.
20) Rashid F, Farook TH, Dudley J. Digital shade matching in dentistry: a systematic review. Dentistry Journal. 2023 Oct 27;11(11):250.