ORIGINAL ARTICLE

Diagnostic Test Accuracy of Color Grab™ App and What a Color?™ App for Porcelain Shade Selection

Karthik Kannaiyan[1], Kiran Kumar Krishanappa S[1] , Vijayendranath Nayak[2] ,Bharathwaj V V[3], Gwee Xiang Qi[4], Arvin Ling Ting Yung[4], Shammie Kong Yan Zhi[4], Terrance Tan Xuan Yu[4]

[1] Department of Prosthodontics, Faculty of Dentistry, Manipal University College Malaysia, Melaka, Malaysia-75150
[2] Department of Oral Medicine and Oral Radiology, Faculty of Dentistry, Manipal University College Malaysia, Melaka, Malaysia-75150
[3] Department of Periodontics, Faculty of Dentistry, Manipal University College Malaysia, Melaka, Malaysia-75150
[4] Faculty of Dentistry, Manipal University College Malaysia, Melaka, Malaysia-75150

ABSTRACT

Introduction: Accurate shade selection is crucial in aesthetic dentistry. Visual method are common but subjective. Spectrophotometer offers precise color measurements but their cost limits everyday use. Mobile apps like Color Grab™ and What a Color?™ offer more accessible options, but their accuracy has not been validated for the use of dentistry. This study compares these apps to spectrophotometric standards to assess their reliability for porcelain shade matching. The purpose of this study was to determine the diagnostic accuracy of Color Grab™ app and What a Color?™ app for porcelain shade matching of dental restorations. **Methods:** A predetermined spectrophotometric L*a*b* values Vita Classical™ Shade Guide (VC) was used as gold standard readings. Color Grab™ app and What a Color™ app was used to capture all 16 shades of VC under standardized light intensity in a photobooth setting, L*a*b* values were recorded down and tabulated. Readings from both apps were compared to the gold standard for assessing diagnostic test accuracy. **Results:** The diagnostic test accuracy of Color Grab™ app showed 48.91%, and for What a Color™ app showed 48.09%. Cohen kappa analysis of both apps were 0.179 and 0.172 respectively, indicating slight agreement. There was no diagnostic relationship between both apps and spectrophotometer.**Conclusion:** The accuracy and reliability of Color Grab™ app and What A Color™ app in dental shade matching are still questionable and requires development and optimization. More further studies and modifications by software companies are needed in order for these apps to be used in shade matching and shade selection in dentistry.
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Keywords: Shade selection, Mobile applications, Diagnostic test accuracy, Spectrophotometer, L*a*b* values

Corresponding Author:
Vijayendranath Nayak S. BDS, MDS
Email: drnayakomr@gmail.com
Tel: +60182680877

INTRODUCTION

Shade selection in dentistry is a procedure which provide patients an aesthetic restoration that harmoniously blends to the patient's existing dentition (1). A successful shade matching can improve aesthetics thus bring patient better satisfaction. Choosing the correct shade has always been a challenge especially in the field of aesthetic dentistry. Shade matching and determination can be done using the most common way which is visual method where available shade guides were compared with the natural dentition of the patient (2). It has the advantage of being cost effective, commercially available and convenient (3). The shade guides available in the market are such as VITA Classical™, Chromascope™, VITAPAN 3D Master™ shade guide (4). But the visual method is known to be subjective, unreliable and the results have high variance due to many effects such as eye fatigue, external light condition, color metamerism, color blindness (2).

Thus, to overcome the disadvantages of visual shade matching, instrumental technique was introduced. These instruments include colorimeters, spectrophotometers (intraoral type and industrial type), digital camera and smartphones as they can obtain readings in quantitative measurements rapidly and objectively (5). Colorimeters are optical reading devices that can measure the absorbance of light wavelength rapidly and consistently. Some studies have shown digital camera giving accurate results but it requires the additional step of transferring the data to a CPU with appropriate software. However, this process has been simplified with smartphones, which is a multitasking device that can be used to capture, store and match shade (6). Amongst the digital instruments, the industrial type spectrophotometer is considered to be the gold standard color measuring device. It gives the most accurate and precise color match that is not affected by color information and surrounding light source but it is a big device and is costly (7).

Alternatively, smartphones are now advanced with computing capability and high-resolution photographic technology enables shade matching to be done in a simpler and more accurate way. It is also portable, cost effective, accessible and faster to use (7).

In recent years, smartphone mobile apps for dentistry use of colour matching have shown promising results (6). There are multiple commercial mobile phone applications available in the market such as T shade™, DMP Chromatcher™, Shade wave™ and Smileshade™ with varying levels of accuracy based on different studies that have been done (7).

Technological evolution has allowed incorporation of the advantages of color matching devices on smartphone, which can be used to capture dedicated photographs for matching dental shade and color references. Color Grab™ from Google Play Store and What a Color?™ from Apple App Store are free to use general purpose software applications that could be used in smartphones. It picks, captures and recognized color simply by pointing the camera. Both apps support common color models such as RGB, HSV, and LAB values. It is used worldwide by designers, artists, developers and color blinds but has not been used in shade matching of teeth in dentistry.

This study was conducted to determine the diagnostic test accuracy of Color Grab™ app and What a Color?™ app for porcelain shade selection and matching in dental restoration compared to the gold standard spectrophotometer. In addition, to assess the agreement of these two apps with the spectrophotometer. The result of this study will enable us to understand if Color Grab™ app and What a Color?™ app which are cost effective apps can be used as an alternative method in routine clinical practice for shade matching accurately. The null hypothesis is this study posits there is no diagnostic accuracy between Color Grab™ app and What a Color?™ app with the spectrophotometer. There is also no agreement between What a Color?™ app with the spectrophotometer.

MATERIALS AND METHODS

Ethical approval

This study had obtained the ethical approval from Institutional Ethical Committee- MUCM/FOD/AR/B10/EC2022[05].

Sample size calculation

The required sample size was calculated according to the disagreement rates between Type I and Type II errors reported in a prior agreement study (8). Referring to the table in the agreement study, with βset at 0.10, α at 0.05, and disagreement rates of 0.30 (6), a minimum of 323 samples was deemed necessary in this study. Since there are 16 shades in a set of Vita Classical shade guide, 323 was rounded up to the nearest multiple of 16, hence total 336 samples needed for this study.

Procedure

Two smartphone application, Color Grab (version 3.9.2 © 2021 Loomatix Ltd.), What a Color? (Version 1.09 © Oleg Brailean) alongside two smartphones (Huawei Nova 2i featuring a built-in 16-megapixel camera, Apple iPhone 15 pro with a built-in 48-megapixel camera) were utilized together with a commercially available tooth shade guide (Vita Classical shade guide) to record the Lightness (L*), red/green value (a*) and blue/yellow value (b*) of individual shade tabs in a controlled environment. Both applications could be downloaded without any charge. The primary rear camera was used for taking the pictures with both smartphones. The smartphones were mounted on a tripod. The tripod was positioned 15cm away from the shade tab and the camera. The shade tab is set up in a light box (PULUZ Folding Portable High 97 CRI Ring Light Photo Lighting Studio Shooting Tent Box) featuring a black backdrop. The light intensity was sustained at 6500K with a D65 lamp (Apple 12W LED Lighting Bulb). The pictures were taken with the long axis of the smartphone aligned parallel to the long axis of the shade tab. A separation of 2 meters was kept between light source and shade tab for optimized environment. For Color Grab™ mobile app, the specific shade tabs were aligned within the camera frame until the central yellow marker in the application was placed at the middle-third of the shade tab. After stabilization, a blue tick will appear and L*a*b* values will be displayed at the top of the application window. For What a Color? ™ mobile application, middle-third of shade tab of a captured image are pinpointed by finger on the screen, a recognized L*a*b* values will be shown at the top of the screen.

Predetermined spectrophotometer L*a*b* values of Vita Classical shade guide by Kim et al. (9) was used as gold standard and reference to identify the predicted shade for both mobile applications. (Figure 1) A predicted shade was obtained from each L*a*b* readings from both mobile applications by correlate to the gold standard readings. A 2x2 table of comparison of predicted shade of both mobile application with actual shade was conducted. Sensitivity, specificity, positive predictive value, negative predictive value and diagnostic test accuracy were calculated by the values in 2x2 table. Cohen kappa (κ) formula were used to measure the agreement between spectrophotometer and both mobile applications.

Shade tab	L*	a*	b*
A2	59.8	0.3	9.2
A3	57.5	0.8	11.8
A3.5	55.4	1.4	13.9
A4	52.4	1.8	14.3
B1	59.8	−1.2	5.2
B2	61.0	−0.7	9.9
B3	55.6	0.8	15.1
B4	55.9	0.9	16.3
C1	56.0	−0.7	7.0
C2	53.9	0.0	10.0
C3	51.7	0.5	11.1
C4	47.4	1.7	12.47
D2	55.2	−0.4	5.5
D3	54.6	0.5	8.6
D4	52.9	−0.2	12.3

Figure 1: Predetermined spectrophotometer L*a*b* values of VITA A1 tab (CIE L*=60.8, a*=-1.0, b*=6.4) and other tabs for the VITA shade guide.

RESULTS

A total of 336 L*a*b* readings of were recorded which 21 readings for each shade tab for all 16 shades in Vita Classical shade guide. Same sample size applied to both mobile applications. The comparison of predicted shade of Color Grab™ application with actual shade is shown in Table Ia, and comparison of predicted shade of What a Color?™ application with actual shade is shown in Table IIa. The diagnostic test accuracy of Color Grab application is 48.91% (Table Ib), and What a Color? application is 48.09% (Table IIb). The Cohen kappa (κ) analysis for 336 readings presented an agreement between the spectrophotometer method and Color Grab™ application (Table III), with a value of 0.179; between the spectrophotometer method and What a Color?™ application (Table IV), with a value of 0.172. Cohen's suggestion of 0 as no agreement, 0.10 to 0.20 as slight agreement, 0.21 to 0.40 as fair agreement, 0.41 to 0.60 as moderate agreement, 0.61 to 0.80 as substantial agreement, 0.81 to 0.99 as near perfect agreement and 1 as perfect agreement was considered as interpretation.

Table III: Cohen Kappa Analysis of Shade Agreement of Colour Grab™ app and spectrophotometer

	Predicted shade	Not predicted shade	Total
Actual shade	77	259	336
Not actual shade	259	4781	5040
Total	336	5040	5376

P0 = 0.904; Pe = 0.883, Cohen kappa is 0.179 (Slight agreement)

Table IV: Comparison of predicted shade of What a Color? ™ app with actual shade

	Predicted shade	Not predicted shade	Total
Actual shade	79	257	336
Not actual shade	285	4755	5040
Total	364	5012	5376

P0 = 0.899; Pe = 0.878, Cohen kappa is 0.172 (Slight agreement)

DISCUSSION

Spectrophotometry was chosen as the principal method for shade assessment due to its well-established reliability and objectivity in color measurement. Unlike visual shade matching, which is inherently subjective and

Table Ia: *Comparison of predicted shade of Color Grab™ app with actual shade*

	Predicted shade	Not predicted shade	Total
Actual shade	77	259	336
Not actual shade	259	4781	5040
Total	336	5040	5376

Table Ib : *Diagnostic test accuracy of Color Grab™ app*

	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Diagnostic test accuracy
Color Grab™ app	22.92%	94.86%	22.92%	94.86%	48.91%

Table IIa: *Comparison of predicted shade of What a Color? ™ app with actual shade*

	Predicted shade	Not predicted shade	Total
Actual shade	79	257	336
Not actual shade	285	4755	5040
Total	364	5012	5376

Table IIb: *Diagnostic test accuracy of What a Color? ™ app*

	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Diagnostic test accuracy
Color Grab™ app	23.51%	94.35%	21.70%	94.87%	48.09%

susceptible to observer bias, lighting inconsistencies, and environmental influences, spectrophotometers offer standardized, quantitative data that minimize inter- and intra-examiner variability. Multiple studies have consistently reported that the spectrophotometer outperforms visual evaluation in terms of accuracy and reproducibility, making it the preferred tool for precise dental shade determination. The Vita Classical™ shade guide was selected for this study because it has been extensively validated and is known to provide a broader and more clinically relevant spectrum of tooth shades compared to other commercially available shade guides (3). Moreover, the application of shade guides to evaluate the accuracy and reliability of clinician shade-matching skills has been employed by various researchers, including Lehman et al. (10), Ortolans et al. (11), and Parameswaran et al. (2), underscoring its recognition as a standard method for validating shade selection techniques.

Conducting the study in an in vitro environment conferred additional methodological advantages. By eliminating patient-dependent variables—such as movement, salivary flow, oral ambient lighting, and tactile discomfort—the researchers ensured a controlled setting that allowed for multiple assessments throughout the day without compromising consistency or data integrity (12). This approach also facilitated repeated testing under standardized conditions, which may not be feasible in typical clinical environments due to time and patient availability constraints.

The present investigation revealed that the Color Grab™ application achieved a diagnostic test accuracy of 48.91%, while the What a Color?™ application demonstrated an accuracy of 48.09%. These figures, coupled with Cohen's kappa values of 0.179 and 0.172 respectively, indicate only slight agreement and highlight the limited reliability of these mobile applications when used independently for clinical shade matching. Such low agreement suggests that relying solely on these applications could result in suboptimal or inconsistent restorative outcomes. This underscores the necessity for their use as adjunct tools alongside more validated methods like visual assessment by trained clinicians or instrumental analysis via spectrophotometry.

Supporting these findings, Haack et al. (12) compared traditional visual shade matching, spectrophotometer use (Vita Easyshade™), and dental shade recognition smartphone applications. Their research similarly concluded that smartphone applications, including the CHROM™ app, produced inconsistent and less precise results compared to both spectrophotometric and visual methods. This reflects the nascent stage of smartphone-based shade matching technologies, signaling that they are not yet viable as stand-alone clinical tools.

Conversely, studies such as those by Fayed et al. (4) and Hari et al. (13) suggest a more optimistic clinical potential for smartphone applications when used as adjuncts. Fayed et al. implemented a digital shade analysis system leveraging the K nearest neighbor (K-NN) classification algorithm, proposing an innovative approach to traditional shade selection processes. Their results indicated that smartphone applications might enhance clinical workflows by offering rapid, user-friendly shade assessments, potentially contributing to efficiency and patient communication. Similarly, Hari et al.'s pilot study observed that the Color Grab™ application yielded comparable shade matching precision to the conventional visual method, advocating for its role as a supplementary tool when visual shade guides are unavailable or to assist less experienced clinicians.

Despite these promising findings, the reliability of smartphone-based shade matching remains challenged by hardware and software limitations inherent to mobile devices. Patonis et al. (14) highlighted that smartphone cameras vary significantly in terms of pixel size, image sensor quality, and optical lens construction. These variations introduce unique distortion patterns and chromatic aberrations that differ not only across models but also between individual devices of the same model, contributing to inconsistent color data capture. Consequently, even under identical settings, sequential image captures may produce divergent readings, thus complicating the repeatability and standardization essential for clinical shade matching.

Complementing this, Alexandre et al. (15) evaluated different smartphones' capacity for accurate color reproduction by comparing RGB and CMY values against scientific reference colors. Their investigation demonstrated that no smartphone currently achieves high-fidelity color accuracy (defined as Delta E < 10), implying that the technical specifications of current mobile cameras limit their utility for precise dental shade determination. This finding emphasizes the urgent need for advancements in smartphone camera technology, image processing algorithms, and calibration methods to bridge this gap.

An important limitation of the current study is the controlled lighting condition under which it was performed—specifically, a fixed color temperature of 6500 K, which is commonly regarded as an ideal daylight simulation standard. However, clinical settings often present highly variable and non-uniform lighting environments, with fluctuations in color temperature and intensity that can substantially impact shade perception and digital imaging outputs. This discrepancy between laboratory and real-world environments suggests that the current results may represent an optimized scenario rather than typical clinical conditions. Therefore, to translate these findings into clinical practice, it is imperative to incorporate ambient lighting assessment tools, such as color temperature meters, prior to image acquisition. This pre-processing step could help adjust and standardize lighting variables, thereby improving the robustness of shade measurements obtained both visually and through digital imaging devices.

This study contributes meaningful data on the current state of smartphone-based shade matching applications, illustrating both their limitations and potential clinical utility. While these applications cannot yet replace established methods, they may serve as convenient adjuncts when combined with visual or spectrophotometric assessments. Future research should prioritize the development of more sophisticated color-matching algorithms that account for device variability and environmental lighting differences. Additionally, standardizing imaging protocols and extensive validation across multiple smartphone models will be critical to advancing the accuracy, repeatability, and clinical adoption of these emerging technologies. Such improvements could ultimately lead to more efficient, objective, and accessible tools for dental shade matching, enhancing restorative outcomes and patient satisfaction.

CONCLUSION

The Color Grab™ app and What a Color?™ app are general color picker purpose software application that provides L*a*b* values which is still not tailored for dental shade matching purposes hence its reliability and accuracy is still questionable. To achieve effective shade matching, one can utilize a blend of technology-driven systems, shade tabs, and reference images. To improve and evaluate the use of these applications in shade selection, further studies required to be done under different light conditions in order to be used in clinical practice.

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