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Comparative Analysis of Visual, Light-Corrected, and Digital Shade Selection Protocols for Natural Teeth Using Vita Classical and VITA 3D-Master Tooth Guides

Shara Ismail Sajini[1], Mohamed Khalil Yousef[1], Abdelrahman Azab[2], Jumana Hamooh[2], Heba Bahgat Abdel-Maksoud[1,3]

Aim: To compare the accuracy and reliability of three shade selection protocols: visual shade selection, visual shade selection with a light-correcting device equipped with a polarization filter, and digital shade selection using VITA Classical (VC) and VITA 3D Master (V3D) shade guides on natural teeth.

Materials and methods: This study compared the accuracy of three shade selection protocols: visual selection under daylight (VSS), visual selection with a light-correcting device using a polarization filter (VWL), and digital selection (DSS) using the VITA Easyshade Advance spectrophotometer. Two experienced dentists used the spectrophotometer to determine the upper right central incisor and canine reference shades. One hundred participants selected shades for these teeth using the VITA Classical and VITA 3D Master shade guides under the three protocols. Shades matching the reference were recorded as correct, and the accuracy of each protocol was evaluated comparatively.

Results: A statistically significant difference was reported between VC and V3D, with the three tested shade selection protocols with $p<0.001$. No statistically significant difference was recorded between the three shade selection protocols while using VC and V3D, with $p=0.261$ and $p=0.503$, respectively. A statistically significant difference resulted between all shade selection protocols' preferred answers, with the highest number of answers found in DSS (72%) followed by VWL (17%) and (VSS) which recorded the least number of answers (11%) ($p<0.001$). No statistically significant difference was observed between males and females regarding the preferred technique ($p=0.580$).

Conclusion: DSS demonstrated the highest accuracy and participant preference, highlighting its potential as the most reliable shade selection protocol.

Keywords: Shade; VITA 3D Master; Easyshade; Spectrophotometer; Light correcting device

1. Department of Restorative Dentistry, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.
2. Operative Dentistry Department, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt.
3. Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.

Corresponding author: Heba B. Abdel-Maksoud , email: habdalmaksod@kau.edu.sa

Introduction

Patients today are increasingly conscious of how their smile affects both their social and professional lives. Therefore, dentists should respect the patient's preferences concerning dental esthetics.[1] This can be achieved by a full understanding of the factors that lead to an esthetically appealing smile. Tooth color, size, and relation to the midline and facial features are some of the key components of a pleasant smile. However, according to recent studies, color matching of the restoration or prosthesis is what determines patient satisfaction and the quality of the dental treatment provided.[2,3] The total effectiveness of any aesthetic restoration is mostly dependent on the right shade match between any dental restoration and adjacent teeth shade selection.[4] Therefore, a thorough examination, precise shade selection, and clear communication are required. Incorrect color selection, on the other hand, is the second most prevalent cause of failure and subsequent recurrence in prosthesis production.[5] Therefore, evaluation of shade-taking and communication protocols has been an area of interest in dental development. This is to enhance the chances of achieving a satisfying indirect restoration appearance.[6–8]

Visual shade matching remains the most popular because of its relative simplicity and inexpensive cost.[9] However, it is a subjective procedure showing huge variations among clinicians and lab technicians, which were explained by researchers using scientific principles and aesthetic aspects of human eyes.[10–12] Several factors related to the clinician were reported to influence the shade-matching performance: color vision impairments, experience, eye color, and fatigue.[13] Other factors such as age and gender, were also believed to be key factors. However, recent studies have suggested otherwise.[14] In contrast, the kind and intensity of the light source, the angle of incidence, the form and texture of the teeth, and other environmental factors all have an impact. All these factors have been shown to make the visual shade-taking technique a more challenging step.[13,15] Moreover, the availability of shade guide systems poses another challenge in the process of shade-taking. It has been noted that the various shade guidance systems now in use do not fully capture the color spectrum of natural teeth. During visual shade matching, the operator selects the most appropriate match to the available shade tab, which is a subjective way that may lead to great variability. Moreover, shade standards are sometimes composed of components that differ from the restorative materials used, which might lead to serious errors. Nowadays, the most frequently utilized system clinically is the VITA Classical shade guide, where the hues are represented by a specific annotation (Letter) and the chroma/value is indicated by a numerical description. Based on this system, many restorative materials that are used now characterize the shade of their products.[16] However, compared to other systems on the market, VITA Linear-guide 3D-Master organizes the color tabs to make this shade scheme more clinically simple and produce better match results. Values, hue, and chroma are indicated using a combinatorial process using letters and numbers in VITA 3D Master tabs, where value is the primary component.

To decrease these variabilities, different shade selection techniques and protocols have been proposed and investigated, such as guidelines and instrumental aids to visual approach along with other digital techniques.[17,18] Many shade selection strategies have been developed for clinical setup, illumination, patient positioning, operator posture, and the use of a common shade guide. To make correct and consistent visual shade selections, it is essential to have a solid understanding of

these procedures.[19] Since lighting conditions in the dental office may vary, color-corrected lighting devices have been proposed to reduce the impact of environmental illumination. The utilization of such devices in conjunction with visual shade guides improved inter-rater agreement and reduced measurement subjectivity.[20,21] Polarization filters have recently been incorporated into light-correcting equipment to lessen reflected light and improve the accuracy of tooth translucency estimation. Moreover, a growing range of computer-aided shade-matching tools is commercially available for clinical application, including colorimeters, spectrophotometers, digital color analyzers, digital cameras, and intraoral scanners.[22] These were shown to be more reliable than the visual method for selecting tooth shades. These instrumental shade-matching devices have the advantages of more consistent communication between professionals and more accurate color choices. [7] The photo-optic measurement permits color quantification, and such systems provide control over external light conditions.[23] However, expensive devices prevent them from being used more widely in clinical practice.[24]

Both visual and instrumental approaches should be utilized whenever feasible since they complement each other and can lead to a predictable esthetic outcome.[25] A comparison of the shade-matching performance between visual, light-aided visual, and instrumental techniques will provide evidence-based data to support clinical decisions when choosing shade selection techniques. This study aimed to evaluate different protocols for shade selection on natural teeth utilizing conventional visual, light correcting devices with polarization filters, and digital shade selection with different shade guide systems. The null hypotheses were as follows: (1) operators using different strategies performed the same in terms of shade selection, and (2) observers' gender and the shade guide they employed did not affect the shade-matching findings.

Materials and Methods

The King Abdulaziz University Research Ethics Committee accepted this study following the World Medical Association's Declaration of Helsinki's guidelines for investigative techniques. (approval number: 333.11.21).

Observer

The current study includes one hundred volunteers from King Abdulaziz University Dental Hospital. To provide appropriate clinical experience, higher levels of dental students were involved (50 final undergraduate sixth-year students and 50 dental interns). Each participant completed a written consent form, was given adequate information about the study methodology, and underwent a color blindness test before recruitment. An Ishihara test for color blindness was made available online for participants to complete.[26] Only participants with normal color vision were included.

Patient

For shade-matching testing, a single subject with a healthy dentition, adequate dental hygiene, and no anterior crowding or restoration was chosen. After signing a written consent form, the chosen patient was cleaned by a professional and advised not to drink any high-staining beverages (coffee, tea) while the study was underway.

Shade guides

VITA Classical shade guide (VC) and the VITA 3D Master (V3D) shade guide (VITA Zahnfabrik, Bad Säckingen, Baden-Württemberg, Germany) were both used in the shade selection test. The original marks on the shade tabs were hidden during the

study, so neither the observers nor the patient knew which shades were chosen.

Shade selection test

To record reference shades of the tested teeth, two experienced dentists recorded the dental shades of (upper right central, and upper right canine) teeth using VITA Easyshade Advance spectrophotometer (VITA, Bad Säckingen, Germany). Measurements were performed for five different cycles (5 days), in each cycle, the shade was recorded five times for each tooth by each dentist. The shades that were repeated more than three times were recorded as a reference. The resultant reference shade for each tooth by Easyshade was also verified using visual shade selection by an experienced dentist. The reference shades were upper right central: A1 (1M2), and upper right canine: A2 (2L 2.5).

The study only included participants who had normal color discrimination (a total of 100 participants, 46 males and 54 females). It was requested that all participants complete shade selection processes in the same dental clinic between 10 a.m. and 3 p.m. The dentist's office was lit by a typical combination of natural light and light from the ceiling lamps. Participants were asked to choose the hue of one patient's upper right canine and upper right central teeth. Shade selection was performed Visually, visual shade selection (VSS) with daylight in the dental office, visually with the use of a light-correcting device with polarization filter (VWL), and digitally, digital shade selection (DSS) by Vita Easy shade. For each condition, two shade guide systems were used: Vita classical and Vita 3D master shade guide systems. The selection tests had no time limit. Between the two observers, the patient was permitted to seal his mouth to rehydrate his teeth. A schematic diagram of the teeth selected, and shade selection techniques is presented in Figure 1.

One experienced dentist was supervising the tests and recording the selected shade. By the end of the experiment, the participants were asked to select the most preferred shade selection technique.

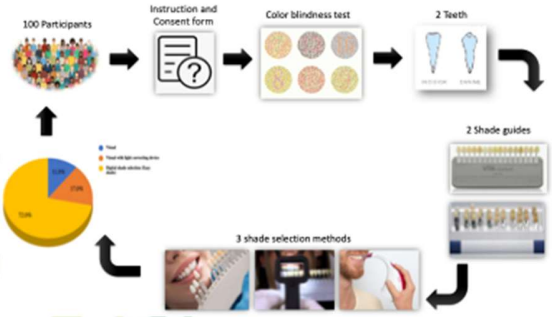

Figure.1: A schematic diagram of the teeth selected, and shade selection techniques

Statistical Analysis

Categorical data was effectively presented to provide clear and compelling information as frequencies (n) and percentages (%). Selected shades that match the reference shades were counted as correct. For every test, the mean and standard deviation values were determined for every group. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to examine the data for normality; the results revealed a non-parametric (not-normal) distribution. Two groups in related samples were compared using the Wilcoxon test, and more than two groups in related samples were compared using the Friedman test. The Chi-square test was used to assess the incidents. A significant threshold of $P < 0.05$ was established. IBM® SPSS® Statistics Version 20 for Windows was used to conduct the statistical analysis.

Results

I) Relation between shade guides:

There was a statistically significant difference between (Vita classical shade; VC)

and (3D master shade, V3D), with the three tested shade selection protocols with $p<0.001$. The highest number of answers for (Vita classical shade) was found in (A1), while the highest number of answers for (3D master shade) was found in (2m1). Figure 2.

II) Relation between shade selection protocols:

There was no statistically significant difference between the three shade selection protocols in using VC and V3D, with $p=0.261$ and $p=0.503$, respectively. The highest number of answers for all protocols was found in (A1) on using VC and (2m1) on using V3D master. Figure 3.

III) Preferred techniques:

There was a statistically significant difference between all shade selection protocols' preferred answers where ($p<0.001$). The highest number of answers was found in DSS (72%), followed by VWL (17%), while the least number of answers was found in (VSS) (11%). Figure 3.

Within each group of males and females, there was a statistically significant difference between all shade selection protocol answers where ($p<0.001$). However, no statistically significant difference was observed between males and females regarding the preferred technique ($p=0.580$). Figure.4

Discussion

The determination of tooth shade is a difficult process that has a significant impact on the aesthetic consequences of restorative procedures. Various attempts have been made to change from subjective visual approaches to objective methods using devices to increase the accuracy and precision of shade identification.[27] The current study has rejected the null hypothesis as significant differences between shade selection techniques in determining the correct shade of different teeth. The second null hypothesis was partially rejected as the observers' gender did not influence the results of shade selection, however, the shade guide used showed a significant effect with the three tested shade selection protocols.

These days, dental shade guides and shade-taking instruments, imaging systems, and color-matching software can be used to visually determine, analyze, and validate tooth shade.[28] Digital methods are more objective and result in better performance of shade matching with higher preference by users when compared to visual methods.[3,7] Spectrophotometers are also easier to use by practitioners without concerns regarding light source or atmosphere influences. This study agrees with previous findings, as digital shade selection presented a significant increase in the performance and preference of the participants when using digital devices. However, these devices are expensive and require observers training to achieve accurate color measurements, which makes their use in dental practice less popular.[29] Light is an essential factor for the success of visual tooth color determination; therefore, light-correcting devices are used to improve the performance of visual shade selection.[1] In the current study, using a light correcting device statistically improved the shade-matching performance in agreement with previous studies.[30,31] Moreover, these devices were found to improve observers' agreement on the value of shade tabs and their capability to match shades.[1] Throughout the study, the device used a polarization filter, which eliminates oblique reflections from glossy surfaces, thus reducing glare and improving the visibility of fine details and translucency parts in dental structures. This could cause improved performance when using the device as earlier studies found that polarization filter has a positive impact on shade selection.[32]

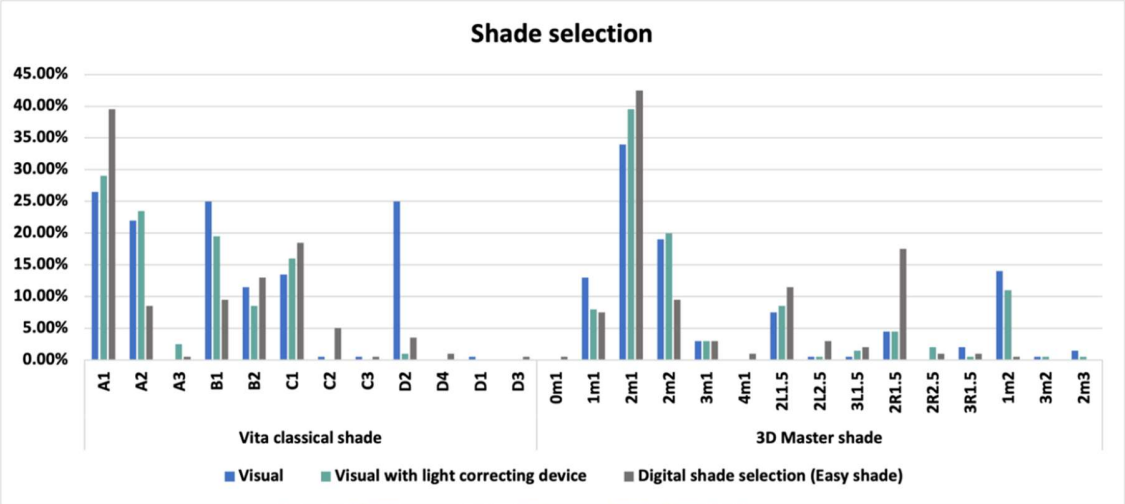

Figure 2: Bar charts representing the shade selection of all tested groups

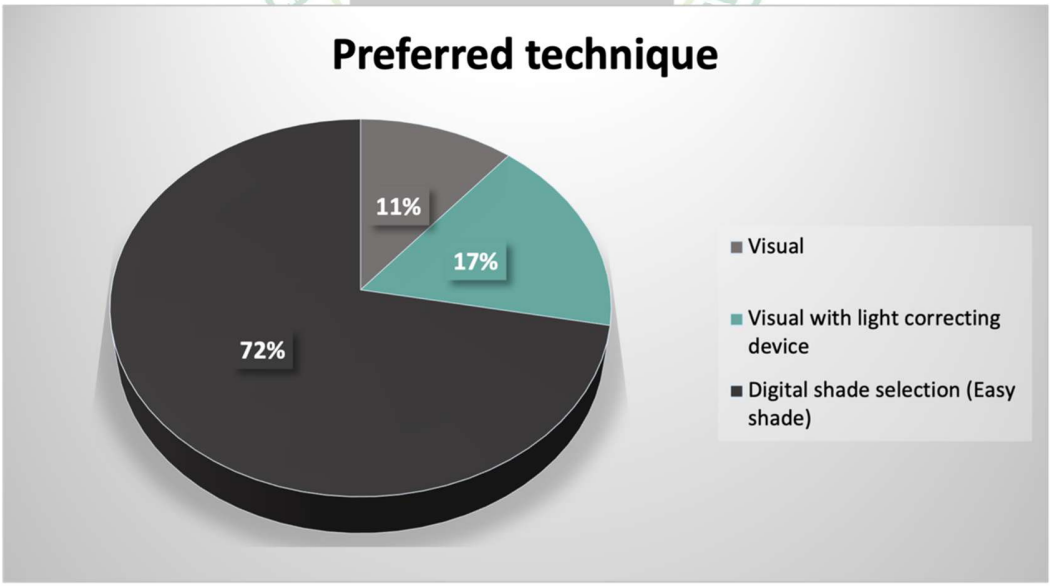

Figure 3: Pie chart illustrating the percentages of participants' preferred shade selection protocols among visual (daylight), visual with a light-correcting device, and digital methods.

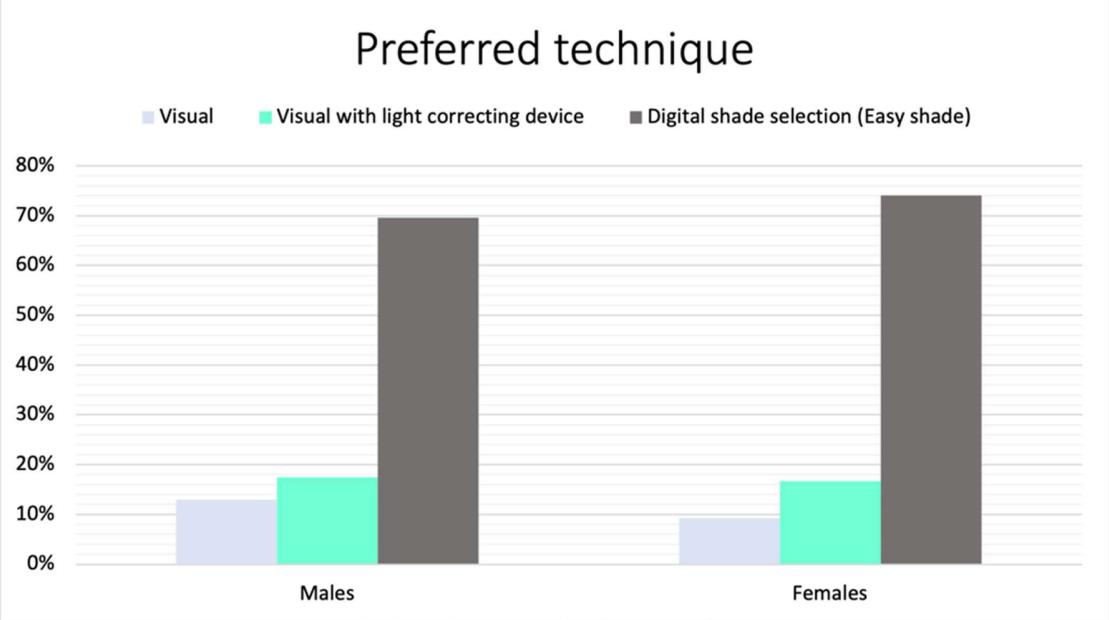

Figure 4: Bar chart representing the most preferred technique of shade selection by all participants

Shade tabs are used for shade choosing in both visual modalities. Since they depend on a variety of factors, including the observer's color perception, lighting conditions, translucency, and the optical properties of the substance, they are regarded as subjective.[33] Two popular shade guide systems were compared in the current study, the VC and the V3D Master. Visually, the V3D shade tabs with no systematic arrangement are more difficult to use than the conventional VC shade tabs. However, visual color matching of the V3D shade tabs was found to be less precise within and among observers.[34] The result of this study agrees with earlier studies that found no differences in shade selection performance, but preference among the observers was towards V3D for easier use. [7,35]

Comparing the current study with earlier ones that investigated shade selection protocols, the use of natural teeth has added value to the outcome of this investigation. Shade selection performance was improved when using light corrective devices. [7] However, the use of natural teeth in the current study mimics the clinical situation better and adds a challenging element in shade selection. A natural tooth has unique unevenly spread hue and translucency, opalescence, with a possible prevalence of fluorescence that makes determining a correct color match more difficult with a significant impact on the matching outcome. Others have also noted that various teeth cause different levels of difficulty in matching. [35] It has been documented previously that variations in the inter-observer reliability were dependent upon the tooth type. This was a motive to compare two different teeth within this study. However, unlike previous investigations, there were no significant differences between the central incisor and the canine in terms of correct shade selection with all techniques. This may be explained by the difference in the participants within both protocols. In the current study, it was one participant with

different observers taking the tooth shade, while previous studies used different participants and only two observers. [35]

Regarding the effect of gender on the performance outcome, no significant differences were found between male and female participants. This agrees with other studies and can be explained by the similarity in the level of participants' experience, unlike earlier studies by Haddad et al. (2009) who stated that female participants outperformed male participants in terms of shade matching. Nonetheless, Miranda (2012) discovered that men exhibited superior color discrimination skills.[36,37] Most of the observers (72%), regardless of their gender, demonstrated a preference for using digital devices for shade selection owing to the preference for the ease of use and knowledge background of better performance.[38-41]

The absence of a time limit for the shade selection method was considered a limitation in our study; hence, eye tiredness might have happened during the trial. Nevertheless, during the shade selection process, the observers were instructed to rest their eyes on a background of neutral color if necessary. Also, the time for shade selection using each technique was not recorded, which would add a valuable element to the comparison.

Conclusion

This study highlights significant differences in the accuracy and participant preferences among the three shade selection protocols evaluated using VITA Classical (VC) and VITA 3D Master (V3D) shade guides. The results demonstrated that:

- DSS achieved the highest accuracy and participant preference, making it the most reliable protocol for shade selection.
- Although no significant differences were observed in the accuracy among the three protocols when VC and V3D were analyzed separately, DSS consistently outperformed the other methods in overall performance.
- VWL, while more accurate than VSS, showed limited preference among participants, indicating a need for further optimization or user training.
- VSS, the least accurate and least preferred method, may benefit from standardization or additional tools to improve reliability.

Furthermore, the lack of significant differences in preferences between males and females suggests that these findings broadly apply across genders. The study emphasizes the importance of incorporating advanced technologies, such as DSS, to enhance shade-matching accuracy and patient satisfaction in clinical practice.

Future research could explore the role of training and experience in improving the performance of visual protocols, expanding the study to include a broader range of tooth types and patient demographics and assessing the cost-effectiveness and accessibility of digital technologies in various clinical settings.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request

Ethics approval and consent to participate

Obtained on February 12, 2021 (Approval No. RECKAU/333.11.21).

Competing interests

The authors declare that they have no competing interests

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