ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)
IJDSIR : Dental Publication Service
Available Online at:www.ijdsir.com
Volume – 9, Issue – 1, January – 2026, Page No. : 23 – 33

A Comparative Analysis of Shade Selection between Smartphone and Conventional Visual Method – An in Vivo Study

[1]Dr. Nikhil Menghani, MDS, Department of Prosthodontics, Crown and Bridge, Dr Ziauddin Ahmad Dental College and Hospital, Aligarh Muslim University, Aligarh, India

[2]Dr. Suraj Visweshwar, MDS, Department of Prosthodontics, Crown and Bridge, Dr Ziauddin Ahmad Dental College and Hospital, Aligarh Muslim University, Aligarh, India

[3]Prof. Abhinav Gupta, MDS, Department of Prosthodontics, Crown and Bridge, Dr Ziauddin Ahmad Dental College and Hospital, Aligarh Muslim University, Aligarh, India

[4]Prof. Geeta Rajput, MDS, Department of Prosthodontics, Crown and Bridge, Dr Ziauddin Ahmad Dental College and Hospital, Aligarh Muslim University, Aligarh, India

[5]Dr. Dhanush R, MDS, Department of Prosthodontics, Crown and Bridge, Dr Ziauddin Ahmad Dental College and Hospital, Aligarh Muslim University, Aligarh, India

Corresponding Author: Dr. Nikhil Menghani, MDS, Department of Prosthodontics, Crown and Bridge, Dr Ziauddin Ahmad Dental College and Hospital, Aligarh Muslim University, Aligarh, India

Citation of this Article: Dr. Nikhil Menghani, Dr. Suraj Visweshwar, Prof. Abhinav Gupta, Prof. Geeta Rajput, Dr. Dhanush R, “A Comparative Analysis of Shade Selection between Smartphone and Conventional Visual Method – An in Vivo Study”, IJDSIR- January – 2026, Volume – 9, Issue – 1, P. No. 23 – 33.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Background: Accurate shade selection is essential for achieving optimal aesthetics in prosthetic rehabilitation. Conventional visual methods are widely used but remain subjective and are influenced by operator experience and lighting conditions. Smartphone-based digital photography has emerged as a potential tool to improve objectivity and reproducibility in shade matching.

Materials and methods: In this randomized controlled study, 100 patients requiring prosthetic rehabilitation were equally divided into two groups: Group 1—visual shade selection and Group 2—digital shade selection using smartphone photography. Three experienced prosthodontists served as independent judges and were blinded to the method used. Each prosthesis was evaluated under three lighting conditions: natural daylight, fluorescent light, and incandescent light. Shade matching was assessed using a 10-point scale, where a score of 10 represented a perfect shade match. Statistical analysis was performed to compare mean shade matching scores between the two methods under each lighting condition.

Results: The smartphone-based digital method demonstrated consistently higher mean shade matching scores across all lighting conditions. Under natural light, statistically significant differences were observed for Judge 1 (t=2.51, p=0.014) and Judge 3 (t=5.02, p<0.001). In fluorescent lighting, all judges reported significantly higher scores with the digital method (p<0.01). Under incandescent light, significant differences were noted for Judge 1 (t=3.55, p<0.001) and Judge 2 (t=2.65, p=0.009). Overall, the digital method achieved significantly higher cumulative ratings across all lighting conditions (p<0.01).

Conclusion: Smartphone-assisted shade selection showed superior accuracy and consistency compared to the conventional visual method, offering an objective and clinically predictable approach for shade selection.

Keywords: shade selection, smartphone, visual shade matching, digital, CIELab

Introduction

Achieving an accurate shade match is a cornerstone of aesthetic dentistry, as colour discrepancies between natural dentition and dental prostheses can compromise treatment outcomes and patient satisfaction. Shade selection, though critical, remains one of the most subjective aspects of prosthodontic treatment, heavily influenced by the clinician's visual acuity, lighting conditions, and surrounding environment.[1,2]

Traditionally, shade matching has relied on visual methods using standardized shade guides such as the VITA Classical or VITA 3D-Master. However, these techniques are inherently limited by human variability and external factors such as lighting, angle of observation, and observer fatigue.[3,4] Metamerism—the phenomenon wherein colours appear differently under varying light sources further complicates visual assessments, often leading to inconsistent outcomes.[5] Natural daylight is generally regarded as the gold standard for shade selection, yet most clinical settings employ artificial lighting, such as fluorescent or incandescent sources, each with unique spectral characteristics that can alter perceived shade.[6] Daylight at 6500 K, designated as the standard illuminant, is characterized by its balanced distribution of visible light wavelengths (400–700 nm) and consistent relative spectral power. Since natural light properties differ, a light source with colour temperature of greater than 5500 K and a CRI greater than 93 is advised for dental shade selection.[7,8]

In recent years, technological advances have led to the emergence of digital tools designed to standardize and objectify the shade selection process. Spectrophotometers, colorimeters, and calibrated photography are among the tools introduced to reduce subjective errors.[9] Notably, the ubiquity of smartphones and their increasingly sophisticated cameras has prompted exploration into their clinical utility for dental shade selection. These mobile platforms offer advantages such as convenience, cost-effectiveness, and improved communication with dental laboratories.[10,11]

Recent developments have also seen intraoral scanners (IOS) being explored for their potential in digital shade selection. Some IOS devices are now equipped with integrated shade-matching capabilities, offering real-time, objective colour assessments alongside digital impressions.[12,13]

The use of a gray card (typically 18% neutral gray) in dental shade selection is primarily intended to standardize colour reproduction by providing a neutral reference point during digital photography. It acts as a calibration tool that eliminates variability caused by lighting, background, and camera sensor bias. This improves the accuracy and reproducibility of shade selection studies and makes comparisons between visual and digital methods more valid.[14,15] Even though the incorporation of a gray card with defined colour coordinates has been shown to effectively compensate for variations in tooth colour produced by different camera diffusers, it demonstrated no significant improvement in images captured using a smartphone.[16,17]

Studies by Albert et al. and Mohammadi et al. have demonstrated promising results using smartphone-based applications and image analysis software for dental shade matching. These tools have shown high reliability and accuracy, often surpassing conventional visual techniques when calibrated and standardized properly.[18,19]

Despite these advancements, there remains a paucity of in vivo studies evaluating the performance of smartphone-based shade selection methods in comparison to traditional visual techniques, particularly under different lighting conditions. Furthermore, the consistency of these methods when evaluated by multiple observers is yet to be fully elucidated.

Hence, the present in vivo study was conducted to compare the accuracy and reliability of digital (smartphone-based) and conventional visual shade selection methods under three lighting conditions—natural daylight, fluorescent light, and incandescent light—using evaluations from 3 independent judges.

Materials and Methods

This in vivo comparative study was conducted at the Department of Prosthodontics to evaluate and compare the accuracy of shade selection between a smartphone-based digital method and the conventional visual method. Ethical clearance was obtained from the Institutional Ethical Committee of the Faculty of Medicine and written informed consent was obtained from all participants.

The null hypothesis was that there is no statistically significant difference in shade selection accuracy between the smartphone-based digital method and the conventional visual method.

A total of 100 patients (64 women and 36 men) were enrolled and randomly divided into two groups (N = 50 each). Sample size was calculated using power analysis with $\alpha = 0.05$ and power = 80%, based on prior pilot data to detect a clinically meaningful difference in shade match scores.

Randomization into the two groups was done using the sealed envelope method:

- Group 1 (Visual Method): Shade selection using the VITA Tooth guide 3D-Master
- Group 2 (Digital Method): Shade selection using smartphone photography and CIELab analysis

To ensure standardization, randomization and shade selection were carried out by two calibrated operators. The Inter-observer reliability was standardized through a structured calibration process conducted prior to data collection. The operators participated in a pre-evaluation training session in which they were instructed on the correct use of the VITA 3D-Master shade guide, including standard positioning, viewing angle and sequence of shade selection.

The inclusion criteria for this study comprised adults aged between 18 and 50 years, presenting with root canal–treated maxillary central incisors indicated for full-coverage crowns, and exhibiting good periodontal health. Patients were excluded if they presented with stained or discoloured teeth, required multi-unit fixed dental prostheses, had parafunctional habits such as bruxism, or demonstrated active periodontal disease.

Materials used

- VITA Tooth guide 3D-Master (VITA Zahnfabrik, Germany)
- Apple iPhone 15 Pro Max
- Adobe Photoshop 7.0 software (Adobe Inc., USA)
- 3M RelyX dual-cure resin cement (Ultimate Clicker, A3 shade; 3M)
- Lithium disilicate crowns (IPS e.max Press, Ivoclar Vivadent, Liechtenstein), with standardized thickness between 1.0–1.5 mm.

Rationale for Visual shade guide

The VITA 3D-Master system offers logical and reproducible shade matching based on value, chroma, and hue. It improves interobserver reliability and clinical accuracy compared to classical shade guide.[20]

Shade matching protocol

All shade selections were conducted between 10:00 AM to 12:00 PM to standardize ambient light. Middle third of the labial surface was selected for shade evaluation due to minimal translucency and consistent colour.[21] The operator–patient distance was maintained at approximately 30 cm, as per guidelines for clinical colour assessment to minimize parallax and ensure visual consistency.[22] Shade selection was finalized within 30 seconds to reduce visual fatigue.

Digital shade selection protocol

The target tooth and closest matching shade tabs were photographed using smartphone (Apple iPhone 15 Pro Max) at 30 cm with no flash, perpendicular to the tooth surface.

The Camera settings were as follows:

- Lens: Wide-angle (24 mm equivalent)
- ISO: Auto
- White Balance: Daylight
- File Format: JPEG

The photographs were imported into Adobe Photoshop (Adobe Systems Inc., San Jose, CA, USA) for colour analysis. The “Magnetic Lasso Tool” was used to outline the area of interest on the tooth, and the “Magic Wand Tool” was applied to remove surface reflections (Fig. 1).

Figure 1a: Intraoral photograph with shade tab (2M1) selected by the practitioner against the maxillary left canine for reference.

Figure 1b: Image uploaded on Adobe Photoshop software for digital shade analysis

Figure 1c: Selection of area of interest using the ‘Magnetic Lasso Tool’ for shade evaluation.

Figure 1d: Surface reflections removed using ‘Magic Wand Tool’

Figure 1e: CIE L*a*b* values measured from the maxillary lateral incisor (middle third).

Figure 1f: CIE L*a*b* values measured from the 2M1 shade tab (middle third).

The CIELab colour system was employed to quantify colour differences in a three-dimensional space, allowing for objective measurement of perceptible differences. In this system, **L*** represents lightness, ranging from 0 (black) to 100 (white); **a*** represents the chroma in green–red axis, with negative values indicating green and positive values indicating red; and **b*** represents the chroma in blue–yellow axis, with negative values indicating blue and positive values indicating yellow. The CIELab system was selected due to its ability to provide precise, reproducible measurements of colour differences that closely correlate with human visual perception.[23]

The colour difference (ΔE) between the natural tooth and each shade tab was calculated as:

$$\Delta E = [(L_{tooth} - L_{shade})^2 + (\alpha_{tooth} - \alpha_{shade})^2 + (b_{tooth} - b_{shade})^2]^{1/2}$$

The ΔE values between each shade and the adjacent tooth were determined and compared with the CIELab system. The shade tab with the lowest ΔE value was considered the best match for that subject. Johnston and Kao identified a ΔE value of 3.7 in the CIELab colour system as the threshold for clinical acceptability in visual perception, with higher values indicating an unacceptable shade match.[24] According to the findings of Della Bona et al., a colour difference (ΔE) value of less than 2 is considered clinically imperceptible to the human eye, whereas values above this threshold are visually detectable.[25]

After completing shade selection of all participants, crown preparations were done and all ceramic crowns were fabricated using the same lithium disilicate material (IPS e.max CAD; Ivoclar Vivadent AG) with a minimum of 1 mm thickness ensured for all restorations. The cementation was done with a standardized resin cement (RelyX Ultimate Clicker, A3 shade; 3M) to ensure procedural consistency. This was done to simulate clinical conditions and reduce metamerism effects.[23]

Three prosthodontists with ≥15 years of experience independently evaluated the final crowns after cementation. The judges were blinded to the group allocation and the shade selection method. To eliminate any disparity in evaluation, all 3 judges underwent colour vision screening using Farnsworth D-15 Test and Ishihara pseudoisochromatic plates under an ophthalmologist.[26] Each judge conducted an independent evaluation of every participant under three standardized lighting conditions as follows:

1) Natural Daylight: This group consisted of all shade evaluations performed under standardized natural daylight. Evaluations were conducted near a north-facing window, ensuring indirect, diffused daylight without direct sun exposure.
2) Fluorescent light: This group included shade evaluations performed under cool-white fluorescent lighting (4000–5000 K). The operatory lighting was switched exclusively to calibrated fluorescent tubes, and colour temperature was verified using a handheld colorimeter before recording observations.
3) Incandescent light: This group comprised shade evaluations performed under warm incandescent illumination (~2800 K). A dedicated incandescent lighting setup was used and colour temperature was confirmed prior to each session.

Internal consistency and reliability among the judges were evaluated using Cronbach's α coefficient. This statistical measure was selected to assess the degree of agreement and consistency in shade-matching scores assigned by judges under the standardized lighting conditions. The values for overall, visual, and digital assessments across all judges were calculated, and the results indicated acceptable reliability (Cronbach's $\alpha > 0.70$) (Table 1).

Table 1: Inter Rater Reliability of Judges Scores on Visual and Digital Method

Method	Number of Judges	Reliability
Overall	3	.80
Visual	3	.73
Digital	3	.83

Note. Cronbach's α > .70 is considered as satisfactory reliability.

All assessments were performed in the same controlled operatory room, where ambient lighting was minimized and external illumination sources were eliminated. A handheld colour-temperature meter was used before each evaluation session to confirm that each light source operated within its intended range. To avoid order bias, the sequence of lighting exposure was randomized for each participant. Judges evaluated the same participant under all lighting conditions in separate sessions, with a minimum interval of one minute to reduce visual memory effects. The shade of prostheses was assessed using a 10-point Visual Analog Scale (VAS) where 10 indicated a perfect shade match.

Results

Data were analysed using SPSS version 21.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including mean and standard deviation (SD), were calculated for all variables. Comparisons of shade match scores between the visual method and the smartphone-based digital method were performed using the independent samples t-test. This parametric test was chosen as it is appropriate for comparing the means of two independent groups to determine whether the observed differences are statistically significant, under the assumption of normally distributed data and approximately equal variances.[27] A p-value of <0.05 was considered statistically significant for all analyses.

The mean, standard deviation, skewness, and kurtosis of the visual and digital techniques for Judges 1, 2, and 3, as well as the overall rating was calculated (Table 2). Based on the results, the data's normality was tested using SPSS's skewness and kurtosis indices, as described by Pallant.28 According to the literature (Byrne, 2010; Garson, 2012; Hair et al., 2010), data is usually acknowledged to be normally distributed with skewness values ranging from -2 to +2, and kurtosis values ranging from -7 to +7. Both the visual method and digital (smartphone-based) method of shade selection demonstrated normally distributed data, as all skewness and kurtosis values fall within the accepted range. The digital method consistently achieved higher mean scores across all three judges and in the total combined rating compared to the visual method (Fig. 2).

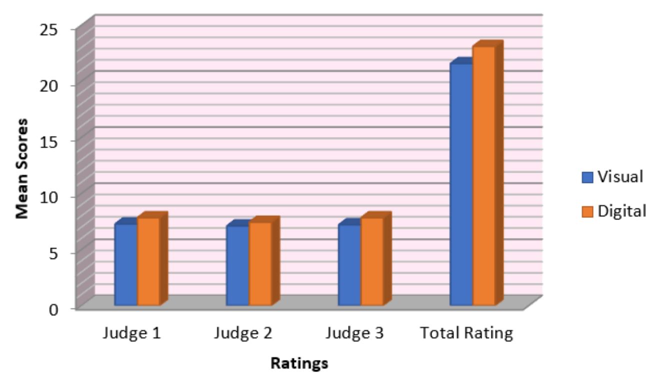

Figure 2: Bar Graph Showing the Distribution of Mean Scores of Judges on Visual and Digital Method

Independent samples t-test was used in Table 3 for scores given by individual judges for comparing visual and digital method on natural source light. Based on the results, it was found that except judge 2 t(98) = 1.14, P = .256, the mean scores of judge 1 t(98) = 2.51, P = .014 and judge 3 t(98) = 5.02, P < .001 for natural light while comparing visual and digital method were found to be statistically significant. Further, it was found that mean score of digital method was greater than visual method in natural light source.

Table 2: Descriptive Statistics

Measure	Visual Method				Digital Method			
	M	SD	Skewness	Kurtosis	M	SD	Skewness	Kurtosis
Judge 1	7.27	0.82	0.22	-0.42	7.83	0.82	-0.41	-0.23
Judge 2	7.10	0.95	0.04	-0.41	7.43	0.76	-0.46	-0.51
Judge 3	7.20	0.98	0.02	-0.42	7.83	0.78	-0.13	-0.54
Total Rating	21.57	2.22	0.06	0.17	23.10	2.05	-0.30	-0.68

Note. N = 100

Independent samples t-test was administered in Table 4 for scores given by individual judges for comparing visual and digital method in Fluorescent source light. Based on results it was found that the mean scores of judge 1 $t(98) = 4.57$, $P < .001$, judge 2 $t(98) = 2.92$, $P = .004$ and judge 3 $t(98) = 4.07$, $P < .001$ in fluorescent source light while comparing visual and digital method were found to be statistically significant. Further, it was found that mean score of digital method was greater than visual method for all three judges.

Table 3: Mean, Standard Deviation, and Independent Samples t-Test for Comparing Visual and Digital Methods in Natural Source Light

Measure	Visual Method		Digital Method		t(98)	p
	M	SD	M	SD		
Judge 1	7.60	0.81	8.00	0.78	2.51*	.014
Judge 2	7.70	1.11	7.90	0.54	1.14	.256
Judge 3	7.30	1.11	8.20	0.61	5.02***	<.001

***p < .001. *p < .05.

Independent samples t-test was used in Table 5 for scores given by individual judges for comparing visual and digital method in Incandescent source light. Based on results it was found that except judge 3 $t(98) = 1.77$, $p = .080$, the mean scores of judge 1 $t(98) = 3.55$, $P < .001$ and judge 2 $t(98) = 2.65$, $P = .009$ in natural source light while comparing visual and digital method were found to be significant. The mean score of digital method was found to be greater than visual method for both the judges 1 and 2.

Independent samples t-test was conducted in Table 6 for total ratings given by individual judges for comparing visual and digital method in Natural, Fluorescent, and Incandescent source light. Based on results it was found that the mean scores on Natural $t(98) = 3.33$, $P < .001$, Fluorescent $t(98) = 4.90$, $P < .001$ and Incandescent $t(98) = 3.25$, $P = .002$ source light while comparing visual and digital method were found to be significant. Further, it was also found that mean score of digital method was found to be greater than visual method for all three source lights (Fig. 3).

Table 4: Mean, Standard Deviation, and Independent Samples t-Test for Comparing Visual and Digital Methods in Fluorescent Source Light

Measure	Visual Method		Digital Method		t(98)	p
	M	SD	M	SD		
Judge 1	6.90	0.84	7.70	0.91	4.57***	<.001
Judge 2	6.80	0.61	7.20	0.76	2.92**	.004
Judge 3	7.10	0.95	7.80	0.76	4.07***	<.001

***p < .001. **p < .01.

Table 5: Mean, Standard Deviation, and Independent Samples t-Test for Comparing Visual and Digital Methods in Incandescent Source Light

Measure	Visual Method		Digital Method		*t*(98)	*p*
	M	*SD*	*M*	*SD*		
Judge 1	7.30	0.65	7.80	0.76	3.55***	<.001
Judge 2	6.80	0.76	7.20	0.76	2.65**	.009
Judge 3	7.20	0.88	7.50	0.81	1.77	.080

***p < .001. **p < .01.

Table 6: Mean, Standard Deviation, and Independent Samples t-Test for Comparing Visual and Digital Methods on Total Rating of Judges Related to Different Sources of Light

Rating	Visual Method		Digital Method		*t*(98)	*p*
	M	*SD*	*M*	*SD*		
Natural	22.60	2.68	24.10	1.72	3.33***	.001
Fluorescent	20.80	1.68	22.70	2.17	4.90***	.001
Incandescent	21.30	1.81	22.50	1.88	3.25**	.002

***p < .001. **p < .01.

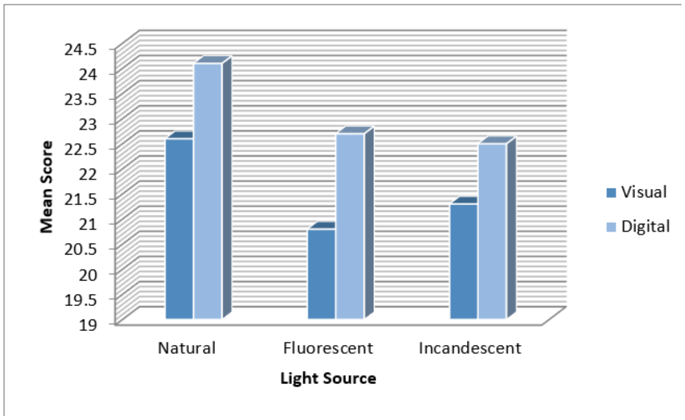

Figure 3: Bar Graph Depicting Mean Scores of Visual and Digital Methods on Total Rating of Judges Related to Different Sources of Light

Discussion

The present study aimed to compare the accuracy of visual and digital shade selection methods under three different lighting conditions—natural, fluorescent, and incandescent using evaluations made by three independent judges. The results clearly demonstrated a consistent trend across all light sources. The digital method yielded higher mean scores than the visual method, indicating superior reliability and consistency. The findings were statistically significant for most comparisons, with exceptions noted in Judge 2 under natural light and Judge 3 under incandescent light, where the differences did not reach statistical significance (Table 3 & Table 5). Notably, inter-rater reliability was also higher for the digital method (α = 0.83) compared to the visual method (α = 0.73), suggesting greater consistency among judges when using the digital approach.

Three different lighting conditions were purposefully selected to replicate clinical scenarios and account for metamerism—whereby the perceived colour of a tooth can vary depending on the light source. Natural daylight is often considered the gold standard for shade matching due to its balanced spectrum.[29] However, clinical environments often rely on artificial lighting, which can significantly alter colour perception.[30] Fluorescent and incandescent lights differ in colour temperature and spectral output; fluorescent light tends to emit a cooler tone, while incandescent light produces a warmer, yellow hue. These variations can lead to inconsistent shade selection during visual assessments.[31]

The superior performance of digital shade selection can be attributed to the objectivity and standardization offered by electronic devices. Unlike the human eye, which is subject to fatigue, colour perception variability, and surrounding influence, digital devices such as spectrophotometers and colorimeters eliminate much of the subjectivity involved in traditional visual matching.[32]

The consistency of results across different judges and lighting conditions further supports the clinical applicability of digital systems in prosthodontics and restorative dentistry. The higher reliability of digital method aligns with previous studies that have shown electronic devices to offer enhanced repeatability and less variation compared to visual techniques.[33]

Since shade selection relies on the clinician's subjective perception, any inconsistencies in this process may result in a prosthesis that fails to harmonize with the patient's natural dentition, thereby compromising aesthetic integrity. The integration of supplementary tools, such as smartphone-based applications, can serve as a valuable adjunct in mitigating discrepancies, facilitating precise shade matching, and ultimately enhancing the overall success of the prosthesis.[34]

The maxillary central incisor was chosen for shade selection as it allows for easier focus during image capture.[35] Unlike posterior teeth, which present challenges due to limited visibility and control, the central incisor's flat surface facilitates accurate visual and digital shade matching. In contrast, canines and premolars have curved surfaces that may introduce inconsistencies in shade assessment.

Consistent with previous researches, the middle third of the anterior teeth was used as it has been identified as the most reliable region for accurate shade determination. This zone is less affected by external factors that may alter perceived colour. In contrast, the incisal third may be influenced by translucency, while the cervical third can be affected by the adjacent gingival tissues, both of which may compromise the shade accuracy.[36]

Albert CJ et al. evaluated colour matching for prostheses using a smartphone-based approach. The study utilized the VITA 3D-MASTER shade guide for shade assessment, applying it to single-tooth photographs to determine the accuracy and reliability of digital shade selection. The study concluded that smartphone-assisted dental imaging is an effective adjunct for shade selection in oral rehabilitation. It enhances communication with the laboratory, streamlining workflow, and improving the accuracy of colour matching, ultimately optimizing prosthetic outcomes.[37] Mohammadi A et al. evaluated the validity and reliability of shade selection with two smartphone applications and Adobe Photoshop. The study, conducted on Vita Lumin Vacuum and 26 Vita 3D-Master shade tabs, concluded that calibrated smartphone images analysed with Adobe Photoshop demonstrated high accuracy and consistency in shade matching.[38]

Despite promising results, certain limitations should be acknowledged. Firstly, only the maxillary central incisor was evaluated, which limits the applicability of the findings to other teeth, particularly posteriors, which present different morphological and optical challenges. The inherent subjectivity of visual shade selection remains a concern, as individual perception and visual acuity may have introduced variability despite using three independent judges. Additionally, patient-specific clinical variables such as enamel translucency, tooth hydration, and age-related discoloration were not considered, though these factors can significantly influence shade accuracy. Although minor variations in the underlying preparation depth may have introduced subtle changes in the translucency of the lithium-disilicate crowns, the use of a standardized fabrication protocol, a minimum ceramic thickness of 1 mm, controlled lighting conditions, and multi-observer evaluation collectively mitigated the potential impact of this limitation. Patient satisfaction and aesthetic perception were not assessed, which are important endpoints in prosthodontic success. Minor inconsistencies in photographic parameters may also have impacted digital evaluations. Lastly, the study focused on short-term accuracy without examining long-term colour stability or performance of the selected shades in the oral environment.

Moreover, although statistical normality was confirmed using skewness and kurtosis values within acceptable ranges, the subjective preferences and visual acuity of judges may still have contributed to residual bias. Also, the study did not assess patient-related factors such as tooth hydration, enamel translucency, or age-related discoloration, all of which could impact shade selection accuracy.[39]

Conclusion

Based on the findings of this study, the smartphone-based digital method demonstrated consistently higher shade match scores than the conventional visual method across all lighting conditions, with several differences reaching statistical significance. These results suggest that smartphone-based shade selection can serve as a reliable and effective alternative to conventional visual methods for achieving optimal aesthetic outcomes.

References

1. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. J Dent. 2010;38 Suppl 2:e2–16.
2. Paravina RD, Ghinea R, Herrera LJ, et al. Color difference thresholds in dentistry. J Esthet Restor Dent. 2015;27(S1):S1–S9.
3. Brewer JD, Wee A, Seghi R. Advances in color matching. Dent Clin North Am. 2004;48(2):341–58.
4. Paul S, Peter A, Pietrobon N, Hämmerle CH. Visual and spectrophotometric shade analysis of human teeth. J Dent Res. 2002;81(8):578–82.
5. Jarad FD, Russell MD, Moss BW. The effect of external light conditions on visual tooth colour selection. Br Dent J. 2005;199(1):37–40.
6. Curd FM, Jasinevicius TR, Graves AE, Lee DJ. Comparison of the accuracy of different light sources in determining tooth shade. J Prosthet Dent. 2006;96(6):391–6.
7. Wee AG, Kang EY, Jere D, et al. Clinical color match of porcelain visual shade-matching systems. J Esthet Restor Dent. 2005;17: 351-357.
8. Gurrea J, Gurrea M, Bruguera A, et al. Evaluation of dental shade guide variability using cross-polarized photography. Int J Periodontics Restorative Dent. 2016;36:e76-e81.
9. Kim-Pusateri S, Brewer JD, Davis EL, Wee AG. Reliability and accuracy of four dental shade-matching devices. J Prosthet Dent. 2009;101(3):193–9.
10. Winkler M, Monasky G, Kwok J. Shade duplication using a digital camera. J Esthet Restor Dent. 2005;17(5):287–93.
11. Ardu S, Benbachir N, Krejci I. Diet analysis: How smartphone photography improves lab communication. Quintessence Int. 2008;39(9):e406–13.
12. Llena C, Lozano A, Amengual J, Forner L. Reliability of color matching by intraoral scanner compared to conventional visual and spectrophotometric methods. J Clin Exp Dent. 2019;11(7):e625–30.
13. Liberato WF, Barreto LM, de Azevedo FM, et al. Evaluation of dental shade matching using a digital intraoral scanner. J Esthet Restor Dent. 2021;33(1):97–102.
14. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. J Dent. 2010;38 Suppl 2:e2–16.
15. Browning WD, Chan DC, Blalock JS, Brackett MG. A comparison of human raters and an intraoral spectrophotometer. Oper Dent. 2009;34(3):337–43
16. Hein S. The use of a standardized gray reference card in dental photography to correct the effects of five commonly used diffusers on the color of 40 extracted human teeth. The international journal of esthetic dentistry. 2016 Jan 1.
17. Sampaio CS, Atria PJ, Hirata R, Jorquera G. Variability of color matching with different digital photography techniques and a gray reference card. The Journal of prosthetic dentistry. 2019 Feb 1;121(2):333-9.
18. Albert CJ, Gomez-Polo C, Martinez V, et al. Smartphone-assisted shade selection in restorative dentistry: An in vivo study. Int J Esthet Dent. 2021;16(3):270–8.
19. Mohammadi A, Zarrinpour N, Khajehahmadi S, et al. Validity and reliability of shade selection using smartphones and Adobe Photoshop. J Dent (Tehran). 2022;19(1):45–52.

20. Haddad W, Jakstat HA, Wicht MJ, et al. Reproducibility of shade selection using the Vita 3D-Master shade guide. J Prosthet Dent. 2009;101 (1):40-44.
21. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. J Dent. 2010;38(Suppl 2):e2–e16.
22. Khashayar G, Bain PA, Salari S, et al. Perceptibility and acceptability thresholds for color differences in dentistry. J Dent. 2014;42(6):637–644.
23. Paravina RD, Powers JM. Esthetic Color Training in Dentistry. St. Louis: Mosby Elsevier; 2004.
24. Johnston WM, Kao E. Assessment of appearance match by visual observation and clinical colorimetry. Journal of dental research. 1989 May;68(5):819-22.
25. Della Bona A, Barrett AA, Rosa V, Pinzetta C. Visual and instrumental agreement in dental shade selection: Three distinct observer populations and shade matching protocols. Dent Mater 2009;25: 276-81.
26. Farnsworth D. The Farnsworth-Munsell 100-Hue and Dichotomous Tests for color vision. J Opt Soc Am. 1943;33:568–578.
27. Bland JM. An Introduction to Medical Statistics. 4th ed. Oxford: Oxford University Press; 2015. p. 331-40.
28. Pallant, Julie. (2007). SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS for Windows Version 15.
29. Joiner A. Tooth colour: a review of the literature. J Dent. 2004;32 Suppl 1:3–12.
30. Della Bona A, Barrett AA. Influence of light source and clinical experience on shade matching. J Prosthodont. 2011;20(7):525–8.
31. Shammas M, Alla RK. Color and shade matching in dentistry. Trends Biomater Artif Organs. 2011 Oct 1;25(4):172-5.
32. Paul S, Peter A, Pietrobon N, Hämmerle CH. Visual and spectrophotometric shade analysis of human teeth. J Dent Res. 2002;81(8):578–82.
33. Paravina RD, Powers JM, Fay RM. Color comparison of two shade guides. Int J Prosthodont. 2002;15(1):73–8.
34. 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.
35. Sinha T, Ranjan M, Chatterjee U, Sinha DK, Chaudhary A, Vijayan A, Sinha Sr DK. A clinical study comparing the maxillary anterior tooth shade and fabricated crown shade of the Western Uttar Pradesh population to commercial shade guides. Cureus. 2023 Mar 3;15(3).
36. 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).
37. Albert CJ, El-Mowafy O, Rubo JH. Shade matching assisted by digital photography and computer software. J Prosthet Dent. 2007;98(3):149–56.
38. Mohammadi A, Kimyai S, Pournaghi-Azar F, et al. Validity and reliability of tooth color selection by smartphone photography and software applications. J Prosthodont. 2021;30(6):541–7.
39. Li Q, Wang YN. Comparison of the color stability of four types of orthodontic clear aligners exposed to staining agents. Int J Oral Sci. 2007;9(3):131–6.