From Eye to AI: Comparative Evaluation of Tooth Shad Selection Using Visual Method, Digital Photography Using Dental Shade Avenue Software, and ChatGPT An In Vivo Study

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Abstract—**Background: Accurate tooth shade selection is essential for achieving optimal dental aesthetics. Traditional visual shade matching is subjective and influenced by environmental and operator-related factors. With the advancement of digital imaging and artificial intelligence (AI), newer methods such as digital photography and AI-assisted analysis have emerged as adjuncts for shade selection. Aim: To comparatively evaluate the accuracy of tooth shade selection using visual method, digital photography using Dental Shade Avenue software, and AI-based analysis using ChatGPT. Materials and Methods: A cross-sectional in vivo study was conducted on 25 dental students at the Department of Prosthodontics, Rajas Dental College and Hospital. Shade selection of maxillary right central incisor (tooth 11) was performed using three methods: visual shade matching with VITA Classical shade guide, digital photography analyzed using Dental Shade Avenue software, and AI-based analysis using ChatGPT. Accuracy was evaluated through intergroup agreement due to the absence of a gold-standard reference. Descriptive statistics and Chi-square test were used for analysis. Results: Digital photography showed the highest consistency and intergroup agreement, followed by ChatGPT. The visual method exhibited greater variability due to subjective factors. Conclusion: Technology-assisted methods improve the consistency of tooth shade selection. Digital photography demonstrated the highest relative accuracy, while ChatGPT showed promising potential as a supportive tool in esthetic dentistry.**

Index Terms—**Tooth shade selection, Visual shade matching, Digital photography, Artificial intelligence, ChatGPT, Dental Shade Avenue, Esthetic dentistry, Prosthodontics, Shade accuracy, Intergroup agreement.**

I. INTRODUCTION

Shade selection is quite possibly the trickiest undertaking in clinical dentistry [1]. The capacity of a dental expert to pick and convey a palatable shade is a critical calculation to accomplish accuracy in terms of aesthetics [2]. Dental aesthetics has become a significant component of modern dentistry, where accurate tooth shade selection plays a vital role in prosthetic and cosmetic outcomes. Matching the natural tooth shade is challenging due to variations in enamel translucency, dentin opacity, lighting conditions, and observer perception [6]. Traditionally, clinicians have relied on visual methods using shade guides, such as the Vita classical or Vita 3D master, to determine the appropriate shade. While, widely used, these three methods are inherently subjective, often influenced by factors such as ambient lighting, operator experience and individual color perception. High resolution images captured under controlled conditions allow for better documentation and analysis of tooth color. This method still requires interpretation by the clinician or software and variability in lighting, camera settings and calibration can impact the reliability of results. With advancements in AI, new tools have been introduced to further standardize and potentially enhance shade matching. While ChatGPT is not inherently trained for dental-specific tasks, its adaptability opens the door for creative appliances in clinical workflows. By assessing the accuracy, consistency and practically each approach in research speaks to determine the potential role of AI in improving current shade selection protocols in dentistry.

II. AIM

To perform a cross-sectional comparison of the accuracy of tooth shade selection using three different methods.

III. OBJECTIVES

1. To evaluate shade selection using the visual method with VITA Classical shade guide.
2. To analyze digital photographs using Dental Shade Avenue software.
3. To evaluate AI-based shade selection using ChatGPT.
4. To compare the accuracy and agreement among the three methods.

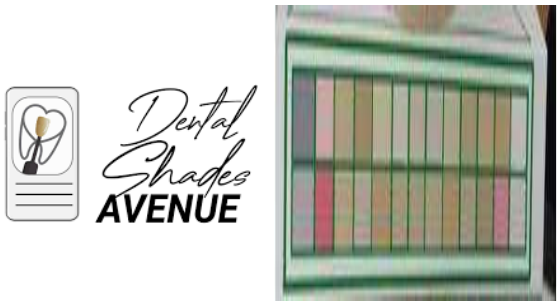
IV. MATERIALS AND METHODS

This cross-sectional in vivo study was conducted among 25 dental students from Rajas Dental College and Hospital in the Department of Prosthodontics. Tooth 11 (maxillary right central incisor) was selected for shade analysis. Inclusion criteria included wide smile (Figure 1) and uniform shade from canine to canine [5]. Exclusion criteria included prosthetically rehabilitated teeth, discolored teeth, fluorosis, and enamel defects (Figure 2). Materials used included VITA Classical shade guide, DSLR camera (100 mm lens), smartphone camera (figure 3), Dental Shade Avenue software, ChatGPT, and colour master (Figure 4) for calibration. Color Master acts as a standard reference for color calibration and integration in Dental Shade Avenue software. It reduces errors caused by lighting and camera variations, ensuring accurate, consistent, and reproducible tooth shade selection. Methodology Shade selection was carried out in a daylight environment (10:00 AM to 1:00 PM).

Figure 1 shows wide smile with uniform shade from canine to canine

Figure 2 shows discolored tooth and fluorosis affected tooth

Figure 3 shows vita classical tooth shade guide, smart phone camera and DSLR camera



s Figure 4 shows dental shade avenue software and color master

V. METHODOLOGY

Shade selection was carried out in a standardized daylight environment (10:00 AM to 1:00 PM).

Experiment 1 – Visual Method: Observers matched tooth shade using VITA Classical shade guide under standardized lighting, neutral background, and a viewing distance of 25–35 cm. Shade matching was completed within 5–7 seconds to reduce eye fatigue.

Experiment 2 – Digital Photography: Standardized photographs were captured using a DSLR camera with a 100 mm lens under daylight conditions with grey background and colour master reference. Images were analyzed using Dental Shade Avenue software to obtain VITA shade recommendations (Figure5).

Figure 5 shows analyzed image from dental shade avenue software

Experiment 3 – AI-Based Analysis: Wide smile photographs captured using a smartphone at 3 feet distance were uploaded to ChatGPT with the prompt "Shade selection based on VITA Classical shade" to obtain shade suggestions (Figure 6).

Figure 6 shows analyzed picture from ChatGPT AI

PARTICIPANTS	VISUAL METHOD BY PROSTHODONTIST	DIGITAL PHOTOGRAPHY [DENTAL SHADE AVENUE]	CHAT GPT [AI BASED]
1	A3 SHADE	A3 SHADE	A3.5 SHADE
2	A1 SHADE	A1 SHADE	A1 SHADE
3	A2 SHADE	A2 SHADE	A1 SHADE
4	B1 SHADE	B1 SHADE	A1 SHADE
5	A1 SHADE	A1 SHADE	A2 SHADE
6	B1 SHADE	B2 SHADE	A1 SHADE
7	A2 SHADE	A2 SHADE	A3 SHADE
8	A1 SHADE	A2 SHADE	B2 SHADE
9	B1 SHADE	B1 SHADE	A1 SHADE
10	A2 SHADE	A2 SHADE	A2 SHADE
11	D2 SHADE	B3 SHADE	A2 SHADE
12	A1 SHADE	A2 SHADE	D1 SHADE
13	A2 SHADE	A2 SHADE	A1 SHADE
14	A1 SHADE	D1 SHADE	A2 SHADE
15	B2 SHADE	A1 SHADE	A2 SHADE
16	A3 SHADE	A3 SHADE	D2 SHADE
17	A3 SHADE	A2 SHADE	A2 SHADE
18	A2 SHADE	B2 SHADE	A1 SHADE

19	A2 SHADE	A2 SHADE	A2 SHADE
20	A2 SHADE	A2 SHADE	B3 SHADE
21	A1 SHADE	A2 SHADE	B2 SHADE
22	A1 SHADE	B2 SHADE	C2 SHADE
23	A2 SHADE	A1 SHADE	B2 SHADE
24	A3 SHADE	A3 SHADE	C3 SHADE
25	A3 SHADE	A3 SHADE	C3 SHADE

Table 1: - shows results from visual method by prosthodontist, digital photography by dental shade avenue and ChatGPT AI

VI. ACCURACY ASSESSMENT AND STATISTICAL ANALYSIS

Since no gold-standard spectrophotometer was used, accuracy was assessed based on intergroup agreement among the three methods. Accuracy (%) was calculated using the formula: (Number of correct matches / Total number of attempts) × 100. Descriptive statistics and Chi-square test were used for categorical agreement with significance level set at $p < 0.05$.

PARTICIPANTS	VISUAL METHOD BY PROSTHODONTIST	DIGITAL PHOTOGRAPHY [DENTAL SHADE AVENUE]	ACCURACY COMPARISON
1	A3 SHADE	A3 SHADE	100%
2	A1 SHADE	A1 SHADE	100%
3	A2 SHADE	A2 SHADE	100%
4	B1 SHADE	B1 SHADE	100%
5	A1 SHADE	A1 SHADE	100%
6	B1 SHADE	B2 SHADE	100%
7	A2 SHADE	A2 SHADE	100%
8	A1 SHADE	A2 SHADE	0
9	B1 SHADE	B1 SHADE	100%
10	A2 SHADE	A2 SHADE	100%
11	D2 SHADE	B3 SHADE	0%
12	A1 SHADE	A2 SHADE	0%
13	A2 SHADE	A2 SHADE	100%
14	A1 SHADE	D1 SHADE	0%
15	B2 SHADE	A1 SHADE	0%
16	A3 SHADE	A3 SHADE	100%
17	A3 SHADE	A2 SHADE	0%
18	A2 SHADE	B2 SHADE	0%
19	A2 SHADE	A2 SHADE	100%
20	A2 SHADE	A2 SHADE	100%
21	A1 SHADE	A2 SHADE	0%
22	A1 SHADE	B2 SHADE	0%
23	A2 SHADE	A1 SHADE	0%
24	A3 SHADE	A3 SHADE	100%
25	A3 SHADE	A3 SHADE	100%
TOTAL NUMBER OF 100% = 14			
TOTAL NUMBER OF 0% = 11			

Table 2:- shows accuracy comparison between visual method and digital photography method by using dental shade avenue software

PARTICIPANTS	VISUAL METHOD BY PROSTHODONTIST	CHAT GPT [AI BASED]	ACCURACY COMPARISON
1	A3 SHADE	A3.5 SHADE	0%
2	A1 SHADE	A1 SHADE	100%
3	A2 SHADE	A1 SHADE	0%
4	B1 SHADE	A1 SHADE	0%
5	A1 SHADE	A2 SHADE	0%
6	B1 SHADE	A1 SHADE	0%
7	A2 SHADE	A3 SHADE	0%
8	A1 SHADE	B2 SHADE	0%
9	B1 SHADE	A1 SHADE	0%
10	A2 SHADE	A2 SHADE	100%
11	D2 SHADE	A2 SHADE	0%
12	A1 SHADE	D1 SHADE	0%
13	A2 SHADE	A1 SHADE	0%
14	A1 SHADE	A2 SHADE	0%
15	B2 SHADE	A2 SHADE	0%
16	A3 SHADE	D2 SHADE	0%
17	A3 SHADE	A2 SHADE	0%
18	A2 SHADE	A1 SHADE	0%
19	A2 SHADE	A2 SHADE	100%
20	A2 SHADE	B3 SHADE	0%
21	A1 SHADE	B2 SHADE	0%
22	A1 SHADE	C2 SHADE	0%
23	A2 SHADE	B2 SHADE	0%
24	A3 SHADE	C3 SHADE	0%
25	A3 SHADE	C3 SHADE	0%
TOTAL NUMBER OF 100% = 3			
TOTAL NUMBER OF 0% = 22			

Table 3: - shows accuracy comparison between visual method and ChatGPT AI

PARTICIPANTS	DIGITAL PHOTOGRAPHY [DENTAL SHADE AVENUE]	CHAT GPT [AI BASED]	ACCURACY COMPARISON
1	A3 SHADE	A3.5 SHADE	0%
2	A1 SHADE	A1 SHADE	100%
3	A2 SHADE	A1 SHADE	0%
4	B1 SHADE	A1 SHADE	0%
5	A1 SHADE	A2 SHADE	0%
6	B2 SHADE	A1 SHADE	0%
7	A2 SHADE	A3 SHADE	0%
8	A2 SHADE	B2 SHADE	0%
9	B1 SHADE	A1 SHADE	0%
10	A2 SHADE	A2 SHADE	100%
11	B3 SHADE	A2 SHADE	0%
12	A2 SHADE	D1 SHADE	0%
13	A2 SHADE	A1 SHADE	0%
14	D1 SHADE	A2 SHADE	0%
15	A1 SHADE	A2 SHADE	0%

16	A3 SHADE	D2 SHADE	0%
17	A2 SHADE	A2 SHADE	100%
18	B2 SHADE	A1 SHADE	0%
19	A2 SHADE	A2 SHADE	100%
20	A2 SHADE	B3 SHADE	0%
21	A2 SHADE	B2 SHADE	0%
22	B2 SHADE	C2 SHADE	0%
23	A1 SHADE	B2 SHADE	0%
24	A3 SHADE	C3 SHADE	0%
25	A3 SHADE	C3 SHADE	0%
TOTAL NUMBER OF 100% = 4			
TOTAL NUMBER OF 0% = 21			

Table 4: - shows accuracy comparison between digital photography method by using dental shade avenue software and ChatGPT AI

PARTICIPANTS	VISUAL METHOD BY PROSTHODONTIST	DIGITAL PHOTOGRAPHY [DENTAL SHADE AVENUE]	CHAT GPT [AI BASED]	ACCURACY COMPARISON
1	A3 SHADE	A3 SHADE	A3.5 SHADE	66%
2	A1 SHADE	A1 SHADE	A1 SHADE	100%
3	A2 SHADE	A2 SHADE	A1 SHADE	66%
4	B1 SHADE	B1 SHADE	A1 SHADE	66%
5	A1 SHADE	A1 SHADE	A2 SHADE	100%
6	B1 SHADE	B2 SHADE	A1 SHADE	0%
7	A2 SHADE	A2 SHADE	A3 SHADE	66%
8	A1 SHADE	A2 SHADE	B2 SHADE	0%
9	B1 SHADE	B1 SHADE	A1 SHADE	66%
10	A2 SHADE	A2 SHADE	A2 SHADE	100%
11	D2 SHADE	B3 SHADE	A2 SHADE	0%
12	A1 SHADE	A2 SHADE	D1 SHADE	0%
13	A2 SHADE	A2 SHADE	A1 SHADE	66%
14	A1 SHADE	D1 SHADE	A2 SHADE	0%
15	B2 SHADE	A1 SHADE	A2 SHADE	0%
16	A3 SHADE	A3 SHADE	D2 SHADE	66%
17	A3 SHADE	A2 SHADE	A2 SHADE	66%
18	A2 SHADE	B2 SHADE	A1 SHADE	0%
19	A2 SHADE	A2 SHADE	A2 SHADE	100%
20	A2 SHADE	A2 SHADE	B3 SHADE	66%
21	A1 SHADE	A2 SHADE	B2 SHADE	0%
22	A1 SHADE	B2 SHADE	C2 SHADE	0%
23	A2 SHADE	A1 SHADE	B2 SHADE	0%
24	A3 SHADE	A3 SHADE	C3 SHADE	66%
25	A3 SHADE	A3 SHADE	C3 SHADE	66%
TOTAL NUMBER OF 100% = 5				
TOTAL NUMBER OF 66% = 11				
TOTAL NUMBER OF 0% = 10				

Table 5: - shows accuracy comparison between visual method, digital photography method by using dental shade avenue software and ChatGPT AI

VII. RESULTS AND DISCUSSION

The results demonstrated that digital photography showed the highest level of agreement and consistency among the three methods. This can be attributed to the objective nature of digital image analysis. The use of standardized photographic protocols, grey background, and colour calibration tools (colour master) reduces variability caused by environmental and operator-related factors. Unlike visual assessment, digital systems analyze pixel-based colour information, minimizing human bias. These findings are consistent with previous studies that highlight the superiority of digital methods in improving reproducibility and documentation in aesthetic dentistry [3].

In contrast, the visual method exhibited the greatest variability, which aligns with its known limitations. Shade selection using conventional shade guides depends heavily on subjective perception, which can be influenced by multiple factors such as ambient lighting conditions, observer experience, eye fatigue, and surrounding colours. Even though the study attempted to standardize conditions (daylight timing, neutral background, limited viewing time), complete elimination of subjectivity is not possible. This explains the inconsistent shade distribution observed across participants in the visual method [3].

The AI-based method using ChatGPT showed moderate agreement, performing better than the visual method in certain comparisons but not exceeding digital photography. This suggests that AI has the potential to reduce operator-dependent variability. ChatGPT likely provided more consistent outputs when similar image inputs and prompts were used. However, discrepancies were observed, which may be due to the fact that ChatGPT is not specifically trained on dental shade databases or calibrated colour systems like VITA. Additionally, variations in smartphone image quality, lighting inconsistencies, and lack of standardized calibration may have influenced AI interpretation[7].

When comparing digital photography with ChatGPT, digital methods remained slightly superior. This can be explained by the use of dedicated dental software algorithms that are specifically designed to interpret tooth colour based on established shade systems. In contrast, ChatGPT functions as a general AI model and lacks domain-specific calibration for precise colour analysis. Nevertheless, the relatively close agreement between these two methods indicates that AI-based tools could evolve into reliable adjuncts in clinical practice with further training and integration.

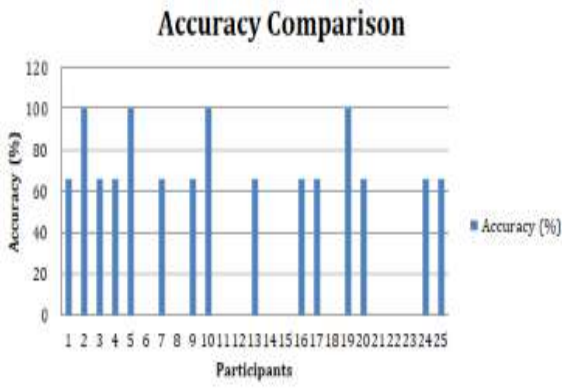
An important observation from this study is that agreement among all three methods was limited, with only a small number of cases showing 100% concordance. This highlights the inherent complexity of tooth shade selection, which is influenced by optical properties such as translucency, fluorescence, and surface texture, in addition to colour. It also reinforces the need for a multimodal approach combining visual judgment, digital tools, and emerging AI technologies for optimal results.

The concept of "relative accuracy" used in this study is crucial for interpretation. Since no spectrophotometer or gold standard was used, accuracy values represent agreement between methods rather than true shade correctness. Therefore, the higher agreement seen with digital photography reflects better consistency, not necessarily absolute precision. Future studies incorporating objective reference devices would provide stronger validation.

From a clinical perspective, the findings suggest that digital photography can serve as a reliable primary method, while AI tools like ChatGPT may function as supportive adjuncts, especially in settings where advanced instruments are unavailable. The visual method, although widely practiced, should ideally be supplemented with technology to improve outcomes.

Overall, this study supports the ongoing transition in dentistry from subjective evaluation toward technology-driven, standardized, and reproducible methods [4]. With further advancements, particularly in training AI models with dental-specific datasets and integrating them with digital imaging systems, the accuracy and reliability of shade selection can be significantly enhanced.

VIII. CHART INTERPRETATION



Overall Accuracy:

Percentage scores (0%, 66%, 100%), so we calculate mean accuracy:

- 100% accuracy: 4 participants (2, 5, 10, 19) → 4 × 100 = 400
- 66% accuracy: 11 participants → 11 × 66 = 726
- 0% accuracy: 10 participants → 10 × 0 = 0

☞ Total score = 400 + 726 = 1126

☞ Mean accuracy = 1126 / 25 = 45.04%

Overall accuracy = ~45%

1. Perfect Matches (100%)
- Occurred when all three methods agreed
- Only 4 cases → 16%
- Indicates full consistency is still limited

2. Partial Matches (66%)
- Most common outcome (44% of cases)
- Usually:
  - Visual = Digital match
  - AI slightly deviates (e.g., A2 vs A1 or A3)

3. Complete Mismatch (0%)
- 40% of cases
- Occurs when:
  - All three methods differ significantly

The comparative analysis demonstrated an overall accuracy of approximately 45% for the AI-based shade selection when evaluated against visual and digital photography methods. While complete agreement among all three methods was observed in only 16% of cases, partial agreement was considerably higher (44%), indicating that the AI system frequently approximates the correct shade but lacks precision. The findings suggest that AI may serve as an adjunct tool but is not yet reliable as a standalone method for dental shade selection.

IX. LIMITATIONS

Absence of a standardized gold-standard shade reference- small sample size- ChatGPT not specifically trained for dental shade analysis- Variability in image capture despite standardization.

X. FUTURE SCOPE

Future studies can include larger sample sizes, multicenter trials, and comparison with spectrophotometers as gold-standard devices. Development of dental-specific AI models trained on shade databases and integration of AI with intraoral scanners and digital shade-matching systems may further improve accuracy in esthetic dentistry [4].

XI. CONCLUSION

Within the limitations of this study, it can be concluded that tooth shade selection accuracy improves as the method becomes more objective and technology-assisted. Digital photography using Dental Shade Avenue software showed the highest intergroup agreement and consistency. AI-based shade selection using ChatGPT demonstrated encouraging relative accuracy and can be considered a supportive adjunct in esthetic dentistry. Conventional visual shade selection remains subjective and operator-dependent.

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