Original Article

DOI: 10.7860/JCDR/2026/81281.23127

Dentistry Section

Analysis of Various Techniques for Tooth Shade Matching: An Umbrella Review

S ADVAITHA NARAYAN[1], MADHURAM KRISHNAMURTHY[2], K SHANMUGAPRIYA[3], ASHOK LEBURU[4]

ABSTRACT

Introduction: Precise shade matching plays a crucial part in restorations, as highlighted by the goal of aesthetic excellence in dentistry, which is moulded by social trends and innovative technologies. Even if conventional approaches are widely used, new digital equipment requires a re-evaluation due to issues like subjective interpretation and unpredictability in shade guides.

Aim: To evaluate and compare the existing literature in order to determine the best reliable dental shade selection methods for tooth colour matching.

Materials and Methods: In the present umbrella review duration of literature search was from January 2000 to February 2025. The PROSPERO database contains the designed and registered protocol of this umbrella review (CRD42023412138). Inclusion criteria included systematic reviews including cross-sectional studies, cohort studies, case-control studies, randomised controlled trials and studies evaluating the impact of accurate tooth shade selection. Exclusion criteria comprises systematic reviews assessing shade selection methods other than instrumental or conventional techniques. In order to create the umbrella review, researchers used the PRISMA principles. The search method included the following terms: "tooth shade," "natural tooth shade," "shade selection," "conventional and instrument shade selection," "digital shade selection," "spectrophotometer shade selection," "colourimeter shade selection" were included. In order to find the applicable systematic reviews, the search terms were AND ((systematic review) OR meta-analysis) were used. Data was sourced from four electronic databases (PubMed, EBSCHO host, Cochrane and Scopus databases) were used to perform a literature search until 2025. The methodological quality and risk of bias of the included systematic reviews were assessed using the AMSTAR 2 (A MeaSurement Tool to Assess Systematic Reviews) checklist. The AMSTAR 2 score for the reviews ranged from 'low' to 'critically low quality'.

Results: Six systematic reviews published between 2012 and 2023 were included in the current umbrella review. Shade selection methods included instrumental approaches {spectrophotometers, colourimeters, photo-colourimetric techniques, Intraoral Scanners (IOS), and digital imaging (cameras/smartphones)} and Conventional approaches {Visual shade selection with shade guides (Vita 3D Master, Vita Lumin)}. Three reviews conducted meta-analysis (using fixed and random effects models). Substantial heterogeneity was reported in pooled estimates. Instrumental shade-matching methods, especially spectrophotometers, provide the most accurate, reliable, and reproducible outcomes in dentistry. Digital approaches (cameras, smartphones, photo-colourimetry) serve as strong alternatives, particularly with standardised protocols and cross-polarisation. Visual methods, although less accurate, retain clinical relevance as affordable, supplemental tools. IOSs currently do not surpass traditional methods in accuracy.

Conclusion: The most exact and precise method of matching shades is to use a spectrophotometer. Though visual shade matching is inconsistent, they are not less accurate than colourimetric measures.

Keywords: Aesthetics, Colour perception, Colourimetry, Dentistry, Dental, Operative, Tooth colour

INTRODUCTION

One of a person's most vital interactive communication abilities is through their smile. A beautiful smile with teeth that are naturally balanced in relation to one another and arranged in a way that complements the patient's lips, gingiva, and face is the ultimate goal of aesthetics in dentistry. One of the trickiest things in restorative dentistry might be precisely matching natural teeth with an artificial restoration. Natural teeth differ widely in terms of colour and form [1].

Determining the colour of the tooth is an important step in restorative dentistry. Both optical approaches and the more contemporary instrumental methods can be used to determine colour. Visual approaches use subjective dental shade that are influenced by factors like as the observer's age, gender, skill level, ambient light, and eye tiredness. Nonetheless, because shade guides are easily accessible, reasonably priced, and user-friendly, the visual technique remains the most popular approach for determining shade [2].

Tooth shade matching has progressed from subjective visual methods to objective instrumental and digital approaches. Visual methods are affordable but inconsistent, while spectrophotometers offer the most reliable results [3]. Emerging tools like hyperspectral imaging and Artificial Intelligence (AI) show superior accuracy but face barriers including high cost, reliance on training datasets, and lack of standardised protocols. Uncertainties remain around calibration, lighting conditions, and clinical integration.

Recent innovations such as hyperspectral imaging and AI are reshaping tooth shade matching. Hyperspectral imaging captures reflectance across multiple wavelengths, enabling precise shade discrimination and validated for in-vivo use [3,4]. AI-driven systems, using intraoral photography and cross-polarised imaging, enhance reproducibility and reduce operator bias [5-7]. While spectrophotometers remain the clinical gold standard, these technologies highlight a shift towards automated, data-driven solutions.

The novelty of this review lies in consolidating traditional and next-generation approaches, providing a broader understanding of current knowledge, persisting uncertainties, and future directions for achieving standardised and clinically feasible shade selection in aesthetic dentistry

The present umbrella review evaluated the accuracy of several instrumental and visual measurements for tooth shade matching in order to analyse the precise method to tooth shade selection.

This is done by combining data from the highest level of evidence using systematic reviews and meta-analyses. In addition, there were methodological flaws in previous systematic studies that were identified.

The present review aimed to critically evaluate the current literature on dental shade selection methods, comparing traditional visual techniques with modern digital approaches. It seeks to highlight the advantages and limitations of each method and identify the most reliable and clinically effective strategies for consistent and accurate tooth colour matching.

The present study aimed to evaluate and compare the existing literature to identify the most reliable dental shade selection methods, encompassing both instrumental and visual approaches, for accurate tooth colour matching.

MATERIALS AND METHODS

The PROSPERO database contains the designed and registered protocol of this umbrella review (CRD42023412138). In order to create the umbrella review, researchers used the PRISMA principles [8].

Review Question

Most accurate method of tooth shade matching is through instrumental or visual methods?

Inclusion criteria (PICOS Framework):

- **Population (P):** Patients requiring dental shade selection for restorative procedures.
- **Intervention (I):** Visual and instrumental methods of tooth shade matching.
- **Comparator (C):** Comparison between different shade selection techniques (visual vs instrumental).
- **Outcomes (O):** Accuracy, reliability, reproducibility, and clinical impact of tooth shade selection methods.
- **Study Design (S):** Systematic reviews and meta-analyses incorporating cross-sectional studies, cohort studies, case-control studies, or randomised controlled trials.

Exclusion criteria: Narrative reviews, scoping reviews, animal studies, case reports, conference abstracts, letters, and opinion papers. Reviews not specifically assessing visual or instrumental methods, non-English publications, and studies with insufficient methodological detail were excluded.

Literature Search

A comprehensive electronic search was performed across PubMed, EBSCOhost, Cochrane Library, and Scopus for studies published between January 2000 and February 2025. The search strategy combined MeSH terms and free-text keywords related to tooth shade selection methods with Boolean operators [Table/Fig-1]. To identify systematic reviews and meta-analyses, search terms were combined with filters for study type. Additionally, the reference lists of all included reviews were manually screened to identify potentially relevant studies.

Two different reviewers (AN and SP) combined through the whole texts and then filtered the titles and abstracts to discover the pertinent reviews. A discussion with a third reviewer (MK) helped settle any disagreements or uncertainties about the reviews' inclusion. In order to fill in any blanks or explain any confusing points, the review writers of the featured studies were contacted.

Database	Search string/Keywords used
PubMed	("tooth shade" OR "natural tooth shade" OR "shade selection" OR "conventional shade selection" OR "instrument shade selection" OR "digital shade selection" OR "spectrophotometer shade selection" OR "colourimeter shade selection") AND ("systematic review" OR "meta-analysis")
EBSCOhost	("tooth shade" OR "shade selection" OR "digital shade selection" OR "conventional shade selection" OR "spectrophotometer shade selection" OR "colourimeter shade selection") AND ("systematic review" OR "meta-analysis")
Cochrane Library	("tooth shade" OR "shade selection" OR "digital shade selection" OR "conventional shade selection" OR "spectrophotometer" OR "colourimeter") in Title, Abstract, Keywords AND ("systematic review" OR "meta-analysis")
Scopus	TITLE-ABS-KEY ("tooth shade" OR "shade selection" OR "digital shade selection" OR "conventional shade selection" OR "spectrophotometer shade selection" OR "colourimeter shade selection") AND TITLE-ABS-KEY ("systematic review" OR "meta-analysis")

[Table/Fig-1]: Keywords and search combinations used in each database.

Data Extraction

The initial author's name and nation, publication year, journal name, quantity of databases searched, search duration, study design type, quality assessment tool, results assessed, study number, subject number, meta-analysis model, particular relative risk estimates with confidence interval, I^2 statistics (to evaluate heterogeneity), and publication bias were all filled out on the data extraction sheets.

Primary outcome: Accuracy of various instrumental and visual measurements for tooth shade matching.

Secondary outcomes: Accurate measurement among instrumental measurements for tooth shade matching. Efficiency of visual method among tooth shade matching methods.

Study Procedure

Methodological quality assessment using AMSTAR 2 tool: The AMSTAR 2 tool, a measurement device for systematic reviews, has sixteen parts that were utilised to assess the methodological quality of the systematic reviews that were included [Table/Fig-2]. The quality of the included reviews was evaluated separately by two reviewers (AN and SP), and if there was a dispute, the third reviewer would settle it (MK). Depending on the number of non-critical flaws, the level of confidence in the review's findings was categorised as high, moderate, low, or critically low. Regardless of the quantity of non-critical defects, a score of more than one critical fault was deemed critically low [9]. The authors were contacted to collect any missing data. Cohen's kappa analysis indicates that the intra-examiner agreement and the agreement between the two reviewers (AN and SP) were used to evaluate the quality of the included reviews.

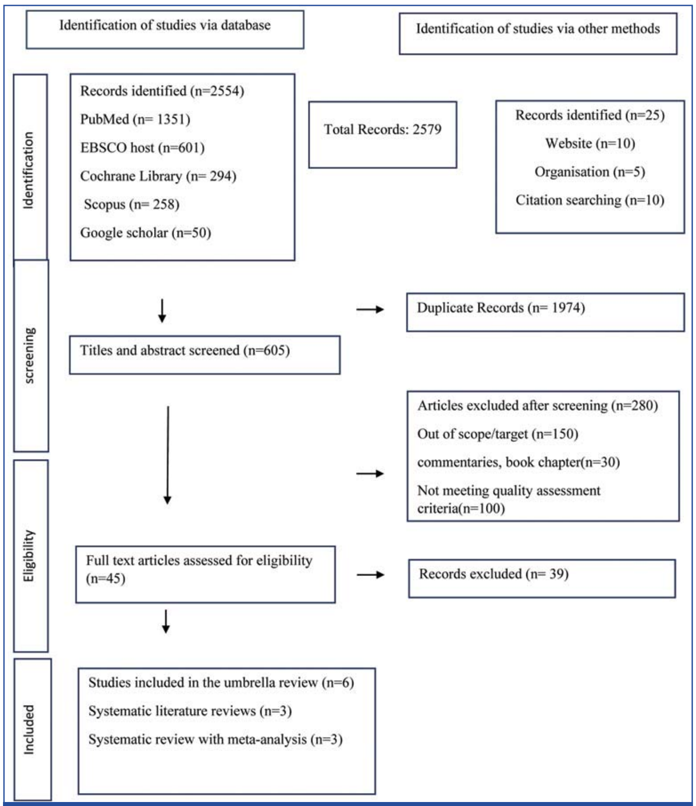
Item No.	Domain/Question	Response Options
1	Did the research questions and inclusion criteria for the review include the components of PICO?	Yes/Partial yes/No
2	Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	Yes/Partial yes/No
3	Did the review authors explain their selection of the study designs for inclusion in the review?	Yes/Partial yes/No
4	Did the review authors use a comprehensive literature search strategy?	Yes/Partial yes/No
5	Did the review authors perform study selection in duplicate?	Yes/No
6	Did the review authors perform data extraction in duplicate?	Yes/No
7	Did the review authors provide a list of excluded studies and justify the exclusions?	Yes/Partial yes/No
8	Did the review authors describe the included studies in adequate detail?	Yes/Partial yes/No
9	Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies included in the review?	Yes/Partial yes/No
10	Did the review authors report on the sources of funding for the studies included in the review?	Yes/No
11	If meta-analysis was performed, did the review authors use appropriate methods for statistical combination of results?	Yes/Partial yes/No/N/A

12	If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?	Yes/Partial yes/No/N/A
13	Did the review authors account for RoB in individual studies when interpreting/discussing the results of the review?	Yes/Partial yes/No
14	Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	Yes/Partial yes/No/N/A
15	If quantitative synthesis was performed, did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its impact?	Yes/Partial yes/No/N/A
16	Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	Yes/No

[Table/Fig-2]: AMSTAR 2 checklist table.

RESULTS

Search results: After careful consideration, Chen H et al., (2012), Raghunathan J et al., (2016), Borse S et al., (2020), Harden L et al., (2022) Morsy N (2023), Rashid F (2023), satisfied the inclusion requirements [Table/Fig-3] [10-15].



[Table/Fig-3]: Flowchart for umbrella review process.

Characteristics of included reviews: The characteristics of the included systematic reviews were showed in [Table/Fig-4]. The systematic reviews were published between September 2012 and October 2023 and published in Quintessence International (n=1), International Journal of Recent Scientific Research (n=1) Journal of Indian Prosthodontic Society (n=1) Materials (n=1) BioMed Central journal (n=1) Dentistry Journal (n=1). The systematic reviews used the following electronic database (PubMed, EBSCO host, Cochrane, web of science, Google scholar and Scopus electronic databases) to identify relevant studies in their review. The search period within the reviews ranged between inception to 2025. The number of studies included in each systematic review ranged from 7 to 85. Amongst the six reviews, only three conducted meta-analyses [12-14] and they used random-effects model and a fixed-effects model for evaluation.

Summary of meta-analysis: The level of heterogeneity among the outcome measures was found to be 92% in the study by Harden L et al., (2022), 98% in the review by Borse S et al., (2020) and more than 50% in Morsy's N review (2023) respectively [12-14]. To determine heterogeneity, these reviews used the I^2 test; however, Harden L et al., (2022) also utilised the Cochrane Q test [13].

Methodological quality: Due to the presence of either one critical defect or no non-critical weakness, the systematic reviews with meta-analysis (Borse S et al., 2020 [12], Harden L et al., 2022 [13], Morsy N et al., 2023 [14]) were given a 'low' grade by AMSTAR 2 [9]. The only critical area that was not fulfilled was the assessment of the presence and possible impact of publication bias (item 15), despite all other critical and non-critical criteria being met. Chen H et al., (2012) [10], Ragunathan J et al., (2016) [11], Rashid F et al., (2023) [15] were the other three reviews that were classified as "critically low" since there was no meta-analysis and there were several critical errors in addition to non-significant problems [9]. Items 2, 4, and 7 were considered key domains, whereas items 1, 2, 3, 4, 7, 8, and 14 were considered fulfilled. The other domains were not [Table/Fig-5]. The included studies have intra- and inter-examiner reliability ratings (AN and SP) of 1 and 0.95 ($p<0.05$), respectively, for scoring the AMSTAR 2 items. These levels indicate 'almost perfect' agreement. Intra- and inter-examiner reliability for AMSTAR 2 item scoring was assessed using the Intraclass Correlation Coefficient (ICC). The null hypothesis of no agreement (ICC=0) was tested using an F-test. Statistical significance was set at $p<0.05$. All analyses were performed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

DISCUSSION

Outcomes assessed: Outcomes addressed by the six included systematic reviews are as follows:

- Instrumental measurements using a spectrometer provided high shade matching outcomes [10]. (Chen H et al., 2012)
- Although visual shade matching was inaccurate, it did not always have lower accuracy than colourimetric measures; the most exact and precise approach is shade matching using a spectrophotometer [11]. (Ragunathan J et al., 2016)
- When it came to shade selection, the Visible Electron Spectrometer (VES Spectrometer) and the photo colourimetric technique both achieved very high levels of accuracy, dependability, and repetition. Repetitive visual shade selection procedures yielded more consistent outcomes in Vita 3d master [12]. (Borse S et al., 2020)
- Instead of relying on colour shade tabs, which may lead to inaccurate shade matching and noticeable colour variances, digital photography and spectrophotometric measurements are a best alternative (Harden L et al., 2022) [13].
- Instrumental shade selection techniques, including spectrophotometers, digital cameras, and smartphones, achieve greater accuracy than traditional visual methods. However, IOSs do not notably enhance shade matching compared to visual selection (Morsy N et al., 2023) [14].
- Non-proximity digital imaging techniques offer more reliable and consistent results compared to traditional visual methods. Under controlled conditions, these digital approaches can match or even surpass the performance of spectrophotometers and colourimeters. However, the study also highlights certain limitations in current research, such as inconsistencies in study quality and variations in methodology. (Rashid F et al., 2023) [15].

Only three results out of six systematic reviews were subject to a meta-analysis: The clinical implications for the reviewed studies indicate that instrumental and digital shade selection methods, including spectrophotometers, VES spectrometers, and digital photography, provide greater accuracy, reliability, and reproducibility than traditional visual techniques; while standardised visual methods, such as Vita 3D-Master, can improve consistency and remain more variable (Borse S et al., 2020) [12]. IOSs alone do not

S. No	Author, year	Name of the journal published	Database searched	Country of the first author	Search period	Language	Meta-analysis performed	Number of studies included	Study design-including studies	Instrument of Quality assessment
1	Chen H et al., 2012 [10]	Quintessence International	PubMed (Medline), Embase Google Scholar	China	Uptojan 82012	English	No	26	In-vitro In-vivo Model studies	PRISMA
2	Ragunathan J et al., 2016 [11]	International Journal of Recent Scientific Research	PubMed (Medline), Embase Google Scholar	India	From last 10 years to August 30,2015	English	No	36	Cohort Case Control Randomised clinical trial Systematic review Meta-analysis	PRISMA
3	Siddesh Borse et al., 2020 [12]	Journal of Indian Prosthodontic Society	PubMed (Medline), Google Scholar Cochrane Library Web of Science	India	Jan 2002-Dec 2018	English	Yes	21	Cross-sectional Comparatative Randomised clinical trial Invitro	Cochrane Collaboration tool
4	Louis Harden et al., 2022 [13]	Materials	Web of Science, EMBASE, PubMed Search engines like Google Scholar and the Cochrane Library	Lebanon	Upto July 15 2021	English	Yes	13	Randomised clinical trial In-vitro	Cochrane Collaboration tool
5	Morsy N et al., 2023 [14]	BMC	PubMed, Scopus, and Web of Science	Egypt	2010 to 2022	English	Yes	7	In-vivo	Cochrane Collaboration tool
6	Rashid F et al., 2023 [15]	Dentistry journal	Web of Science, PubMed Scopus	Australia	Upto October 2023	English	No	85	Research articles, clinical trials, clinical case reports and case series, dental techniques, and short communications	JBI Tool, GRADEpro GDT

[Table/Fig-4]: Characteristics of included reviews [10-15].

Systematic Review/ Meta-analysis	AMSTAR 2 Rating	Critical Weakness Identified	Notes
Borse S et al., 2020 [12]	Low	Item 15 -Publication bias not assessed	All other critical & non-critical domains met
Hardan L et al., 2022 [13]	Low	Item 15 - Publication bias not assessed	Otherwise adequate
Morsy N et al., 2023 [14]	Low	Item 15 - Publication bias not assessed	Otherwise adequate
Chen H et al., 2012 [10]	Critically low	Multiple critical weaknesses; no meta-analysis	Several additional non-critical weaknesses
Raghunathan J et al., 2016 [11]	Critically low	Multiple critical weaknesses; no meta-analysis	Several additional non-critical weaknesses
Rashid F et al., 2023 [15]	Critically low	Multiple critical weaknesses; no meta-analysis	Several additional non-critical weaknesses

[Table/Fig-5]: AMSTAR 2 overall confidence ratings of included reviews [10-15].
Key Domains Considered Critical in AMSTAR 2
- Key critical domains: Items 2, 4, 7
- Other fulfilled items: 1, 2, 3, 4, 7, 8, 14
- Unfulfilled domains: Remaining items

significantly enhance shade matching and should be complemented with objective measurements. Clinically, these findings support the use of instrumental or digital protocols under controlled lighting, combined with visual verification, to optimise aesthetic outcomes and minimise colour discrepancies in restorative dentistry.

For pairwise meta-analysis, the two models used were fixed effect and random effect model. In case of heterogeneity amongst studies included in a meta-analysis random effect models were used [16]. Borse S et al., 2020, Harden L et al., 2022 and Morsy N et al., 2023 used random effect models for quantitative analysis showing a substantial heterogeneity in their meta-analysis [12-14]. The three reviews that performed a meta-analysis did not assess and report on publication bias.

Principal findings and possible explanations: The capacity of the observer or equipment to provide repeated results and consistency of each stage of a given measurement technique, such as maintaining a stable environment and obtaining the same placement point to assess the shade, are the two main factors that determine the precision of colour measurement [17].

Harden L et al., (2022) highlighted the effectiveness of the Smile Lite MDP device in improving shade matching accuracy in mobile dental photography [13]. Beverly L (2021) further emphasised that incorporating a cross-polarising filter in the Smile Lite MDP significantly enhances photographic shade assessment [18]. Additionally, Alfouzan AF et al., (2017) reported that the Vita Linearguide 3D-Master shade guide provides more accurate shade comparisons than the Vita Lumina, supporting its use for precise visual shade selection [19].

Non-proximity equipment, like a digital camera, records hues from a distance. Advanced digital cameras, IOSs and smartphone cameras are illustrations of non-proximity instruments used in dentistry for shade matching. A contact-based instrument assesses an object's colour by contacting its surface directly. In the 1970s, colourimeters and spectrophotometers were initially used in dentistry as contact-based instruments for colour measurement [15].

Tabatabaian F et al., (2021) reported that spectrophotometers, positioned close to the tooth surface, focus on a single point, yielding high accuracy and precision in shade selection. In contrast, IOS scan a larger area, making them more susceptible to ambient light and positioning errors, which can compromise their reliability. Clinically, this suggests that while IOS are useful for digital workflows, spectrophotometers remain superior for precise tooth shade assessment, particularly in aesthetic restorations [20].

Spectrophotometers, photo colourimeters, digital imaging scanners (SVMAs), and cross-polarised photography made up the instrumental part of the procedure. The Vita Easy Shadow (VES) spectrophotometer's principal value lies in the fact that it reduces the visual shade approach's subjective inaccuracy. A spectrophotometer can distinguish between a colour difference of 1 ΔE and a colour difference of 3.7 ΔE that is visible to the human eye [12].

The intraoral digital spectrophotometer performed much better with incandescent light when it came to accurately matching light hues, according to a randomised trial that compared the impacts of filtered and LED light sources [21].

Digital imaging and colourimeter are auxiliary methods to visual measurement when a spectrophotometer or colourimeter not available (Ragunathan J et al., 2016) [11]. Two methods of measuring shadow were employed by digital cameras in the included studies in the systematic review (Chen H et al., 2012) [10]. Using a digital camera to record photographs of the sample and shade guide tabs, some researchers conducted shade matching processes visually in a simulated clinical setting. Others utilised the sample image to estimate ΔE values using colour calculator software [22,23].

Visual shade selection technique can therefore be used as a supplement to Digital methods to increase accuracy. Due to its affordability and ease of use, visual shade evaluation may be performed in cases where precise colour reproduction is not required [11]. Small aperture colourimeters can result in significant edge loss effects [24], which is a drawback of colourimeters. For this reason, several researchers have suggested that visual control should be used in conjunction with instrumental shade matching approaches [25].

Quality of the individual systematic reviews: "A Measurement Tool to Assess Systematic Reviews" (AMSTAR-2) in this extensive investigation was used because it provides dependable outcomes, excellent validity, and agreement when applied to the assessment of systematic review quality [26]. As of right now, this tool is the only means to assess how comprehensive systematic reviews are. You may use this tool on your own, and it is more objective [27]. Overall number of systematic review publications has increased lately. The aim of systematic reviews is to locate, assess, and summarise the findings of all relevant individual research pertaining to a health-related subject. This allows decision makers access the available data more easily [28].

Therefore, it is crucial to take into account the calibre of the clinical studies that are a part of a systematic review in order to assess the calibre of the documentation produced by a later meta-analysis. 'Critically low' was the quality rating given to three of the systematic reviews that did not include meta-analysis, while three additional reviews were deemed 'low'. A review's high AMSTAR score is no guarantee of high-quality original clinical studies. Upon evaluating the existence and potential influence of publication bias, all six systematic reviews were given a score of "No" (item 15 in AMSTAR 2 checklist)

Failure to publish research results based on the direction or intensity of such findings is known as publication bias [29]. This might lead to the exclusion of research with statistically insignificant or negative outcomes from publication in favour of those with statistically significant positive results [30]. "That which is created on all levels of government, academia, business and industry in print and electronic media, but which is not controlled by commercial publishers" is the definition of grey literature [31]. Grey literature searches may broaden review coverage and reduce publication bias, but they also carry the risk of revealing prejudiced or unscientific articles. Eliminating unpublished papers may jeopardise the validity/reliability of meta-analyses and the specificity of systematic reviews [32]. Regardless of their level of publishing, it is advised that all writers of systematic reviews do a thorough literature search.

The present umbrella review provided a comprehensive synthesis of the available evidence on various tooth shade matching approaches, presenting robust, evidence-based findings on the accuracy of both instrumental and visual methods. The review has several notable strengths. First, the protocol was prospectively registered in the PROSPERO database, ensuring transparency. Second, a thorough literature search was conducted across four major electronic databases, minimising the risk of overlooking relevant studies. Third, conflicts arising during study selection and data extraction were resolved by a third independent reviewer, enhancing methodological rigour. Finally, the quality of the included reviews was systematically appraised using the AMSTAR 2 tool, in line with standard evaluation procedures.

Future research should focus on conducting high-quality, standardised trials and systematic reviews to minimise methodological heterogeneity and strengthen the evidence base. Advances such as AI, hyperspectral imaging, and enhanced IOS algorithms should be explored, alongside the development of standardised protocols for digital imaging and lighting, to improve accuracy and consistency in shade selection.

Limitation(s)

The present umbrella review has certain limitations. Only three of the included systematic reviews performed a meta-analysis, thereby limiting the scope of quantitative synthesis. Several of the reviews also exhibited methodological shortcomings, which may have influenced the strength of the evidence. Additionally, systematic reviews that were unpublished or not available in English were excluded, introducing the potential for publication and language bias.

CONCLUSION(S)

The most exact and precise method of matching shades is to use a spectrophotometer. Though visual shade matching is inconsistent, they are not less accurate than colourimetric measures. Colour measurements using digital photography and intraoral scanners have a lot of promise for accuracy. Furthermore, the comparison of various shade-matching results and the regulation of shade-matching processes need controlled criteria. Therefore, technology-based methods, shade tabs, and reference images are necessary for proper shade matching.

REFERENCES

[1] Joiner A. Tooth colour: A review of the literature. J Dent. 2004;32(3):3-12. Doi: 10.1016/j.jdent.2003.10.013.
[2] Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent. 2007;97(4):200-08. Doi: 10.1016/j.prosdent.2007.02.012.
[3] Li Q, Wang Y, Wang YN. In vivo validation of hyperspectral imaging for dental colour measurement. J Dent. 2023;137:104711. Doi: 10.1016/j.jdent.2023.104711. PMID:36363950.
[4] Tejada-Casado M, Ghinea R, Martínez-Domingo MA, Pérez MM, Cardona JC, Ruiz-López J, et al. Validation of a hyperspectral imaging system for color measurement of in vivo dental structures. Micromachines (Basel). 2022;13(11):1929. Doi:10.3390/mi13111929.
[5] Karcioglu AA, Efitli E, Simsek E, Ozdogan A, Karatas F, Senocak T. ML-based tooth shade assessment to prevent metamerism in different clinic lights. Lasers Med Sci. 2025;40(1):39. Doi: 10.1007/s10103-025-04297-y. PMID: 39849248; PMCID: PMC11757855.
[6] Abduo J, Al-Ezzi M. Artificial intelligence in prosthodontic shade selection: A narrative review. Prosthesis. 2024;6(6):92. Doi: 10.3390/prosthesis6060092.
[7] Chen H, Xu Y, Zhang Y, Wang Y. Digital dental shade matching using cross-polarized intraoral imaging and machine learning. Sensors (Basel). 2018;18(9):3051. Doi: 10.3390/s18093051.
[8] Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med. 2009;6(7):e1000097. Doi: 10.1371/journal.pmed.1000097.
[9] Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, et al. AMSTAR 2: A critical appraisal tool for systematic reviews that include randomized or non-randomized studies of healthcare interventions, or both. BMJ. 2017;358:j4008. Doi: 10.1136/bmj.j4008.
[10] Chen H, Huang J, Dong XP, Qian J, He J, Qu X, et al. A systematic review of visual and instrumental measurements for tooth shade matching. Quintessence Int. 2012;43(8):649-59. PMID: 23034418.
[11] Raghunathan J, Ramesh AS, Prabhu K, Gayathri R. A systematic review of efficacy of shade matching in prosthodontics. Int J Recent Sci Res. 2016;7(4):9949-54. PMID: PMC10061675.
[12] Borse S, Chaware SH. Tooth shade analysis and selection in prosthodontics: A systematic review and meta-analysis. J Indian Prosthodont Soc. 2020;20(2):131-40. Doi: 10.4103/jips.jips_399_19.
[13] Hardan L, Bourgi R, Cuevas-Suárez CE, Lukomska-Szymanska M, Monjarás-Ávila AJ, Zarow M, et al. Novel trends in dental colour match using different shade selection methods: A systematic review and meta-analysis. Materials (Basel). 2022;15(2):468. Doi: 10.3390/ma15020468.
[14] Morsy N, Holiel AA. Colour difference for shade determination with visual and instrumental methods: A systematic review and meta-analysis. Syst Rev. 2023;12:95. Doi: 10.1186/s13643-023-02263-9.
[15] Rashid F, Farook TH, Dudley J. Digital shade matching in dentistry: A systematic review. Dent J (Basel). 2023;11(11):250. Doi: 10.3390/dj11110250.
[16] Higgins JPT, Green S. Cochrane handbook for systematic reviews of interventions. Chichester: Wiley-Blackwell; 2011.
[17] Park JH, Lee YK, Lim BS. Influence of illuminants on the colour distribution of shade guides. J Prosthet Dent. 2006;96(6):402-11. Doi:10.1016/j.prosdent.2006.10.007. PMID:17174657.
[18] Beverly L. Protocols for mobile dental photography with auxiliary lighting: By Louis Hardan. Cranio. Batavia, IL, USA: Quintessence Publishing; 2020;39(2). 128 pp. Available from: https://doi.org/10.1080/08869634.2021.1876427.

[19] Alfouzan AF, Alqahtani HM, Tashkandi EA. The effect of colour training of dental students on dental shade matching quality. J EsthetRestor Dent. 2017;29(5):346-51. Doi:10.1111/jerd.12284.

[20] Tabatabaian F, Beyabanaki E, Alirezaei P, Epakchi S. Visual and digital tooth shade selection methods, related effective factors and conditions, and their accuracy and precision: A literature review. J Esthet Restor Dent. 2021;33(6):1084-104. Doi:10.1111/jerd.12770.

[21] Chitrarsu VK, Chidambaranathan AS, Balasubramaniam M. Analysis of shade matching in natural dentitions using intraoral digital spectrophotometer in LED and filtered LED light sources. J Prosthodont. 2019;28(1):e68-e73. Doi: 10.1111/jopr.12665.

[22] Jarad FD, Russell MD, Moss BW. The use of digital imaging for colour matching and communication in restorative dentistry. Br Dent J. 2005;199(1):43-49. Doi: 10.1038/sj.bdj.4812559.

[23] Elter A, Caniklioğlu B, Değer S, Ozen J. The reliability of digital cameras for colour selection. J Prosthet Dent. 2005;18(5):438-40.

[24] Bolt RA, ten Bosch JJ, Coops JC. Influence of window size in small-window colour measurement, particularly of teeth. Phys Med Biol. 1994;39(7):1133-42. Doi: 10.1088/0031-9155/39/7/006.

[25] Gehrke P, Riekeberg U, Fackler O, Dhom G. Comparison of in vivo visual, spectrophotometric and colourimetric shade determination of teeth and implant-supported crowns. Int J Comput Dent. 2009;12(3):247-63.

[26] Shea BJ, Hamel C, Wells GA, Bouter LM, Kristjansson E, Grimshaw J, et al. AMSTAR is a reliable and valid measurement tool to assess the methodological quality of systematic reviews. J Clin Epidemiol. 2009;62(10):1013-20. Doi: 10.1016/j.jclinepi.2008.10.009.

[27] Sharif MR, Janjua N, Ali HH, Ahmed F. Systematic reviews explained: AMSTAR—how to tell the good from the bad and the ugly. J Pak Med Assoc. 2013;63(1):9-16.

[28] Gopalakrishnan S, Ganeshkumar P. Systematic reviews and meta-analysis: Understanding the best evidence in primary healthcare. J Family Med Prim Care. 2013;2(1):09-14. Doi: 10.4103/2249-4863.109934.

[29] DeVito NJ, Goldacre B. Catalogue of bias: Publication bias. BMJ Evid Based Med. 2019;24(2):53-54. Doi: 10.1136/bmjebm-2018-111107.

[30] Nair AS. Publication bias-importance of studies with negative results! Indian J Anaesth. 2019;63(6):505-07. Doi: 10.4103/ija.IJA_142_19.

[31] Paez A. Gray literature: An important resource in systematic reviews. J Evid Based Med. 2017;10(3):233-40. Doi: 10.1111/jebm.12266.

[32] McAuley L, Pham B, Tugwell P, Moher D. Does the inclusion of grey literature influence estimates of intervention effectiveness reported in meta-analyses? Lancet. 2000;356(9237):1228-31. Doi: 10.1016/S0140-6736(00)02786-0.

PARTICULARS OF CONTRIBUTORS:

1. Lecturer, Department of Conservative Dentistry and Endodontics, Sri Ramachandra Institute of Higher Education and Research, Chennai, Tamil Nadu, India.
2. Professor and Head, Department of Conservative Dentistry and Endodontics, Karpaga Vinayaga Institute of Dental Science, Chennai, Tamil Nadu, India.
3. Postgraduate Resident, Department of Conservative Dentistry and Endodontics, Karpaga Vinayaga Institute of Dental Science, Chennai, Tamil Nadu, India.
4. Professor, Department of Conservative Dentistry and Endodontics, Karpaga Vinayaga Institute of Dental Science, Chennai, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
S Advaitha Narayan,
Flat No.1 Ground Floor, Ramanad Apartment, No. 9, 1st Cross Street, United India Colony, Kodambakkam, Chennai-600024, Tamil Nadu, India.
E-mail: sadvaitha@yahoo.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Aug 13, 2025
- Manual Googling: Oct 09, 2025
- iThenticate Software: Oct 11, 2025 (9%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Jun 12, 2025**
Date of Peer Review: **Aug 20, 2025**
Date of Acceptance: **Oct 14, 2025**
Date of Publishing: **Apr 01, 2026**