Review

Tooth shade analysis and selection in prosthodontics: A systematic review and meta-analysis

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Abstract

Aim: To evaluate the methods of the dental shade selection and provide a summary of different factors affecting the shade selection.

Design and Setting: The systematic review and meta-analysis.

Materials and Methods: The electronic search of the peer-review articles between 2002 and 2018 was carried out the by using the PRISMA guidelines. A total twenty-one studies related to the visual shade methods, instrumental shade methods, and the factors affecting the shade selections was evaluated. The search strategy was based on the PICOS framework.

Statistical Analysis: There was statistically significant heterogeneity (Q = 1038.1518, df = 20, and $P < 0.0001$). The statistics of fixed-effect model reported an MD of − 0.0970 (95% CI = −0.1391, −0.0549). The random-effect model reported an MD of − 0.0862 (95% CI = −0.5866, 0.4142).

Result: The review evaluated the 21 studies of tooth colour science that met with the inclusion criteria and search criteria. The meta-analysis of the 21 combined studies reported acceptable homogeneity ($i^2 = 98\%$) which indicates a statistically significant difference between the treatment and control groups.

Conclusion: The VES spectrophotometer reported the highest accuracy, reliability, and repeatability in shade selection followed by photo colorimetric method. The Vita 3D master shows more consistent results in repetitive shade selection. Knowledge and training of the shade selection protocol are necessary for proper shade matching

Keywords: Photo colorimeter, visual shade, Vita three-dimensional master, vita Easy Shade spectrophotometer

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INTRODUCTION

The selection of the color of the natural teeth is the most significant and challenging task of restorative dentistry. Many restorations are failed due to inadequate color selection. The color of the final restoration should match with the natural color of the tooth, particularly restoration and replacement of the anterior teeth either by composite or ceramic materials.[1] The selection of the color of missing teeth that harmonize with the adjacent teeth and surrounding gingival tissue (emergence profile) is the most complex step in prosthetic dentistry.[2] The increase in esthetic demand of the patient, particularly restoration by

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laminates and veneers, signifies the importance of color selection in esthetic dentistry.[1,2]

The two main methods for shade matching are the conventional visual method using shade tabs, typically tooth shaped, and the instrumental method using color-measuring devices.

The visual shade guide is the most common method. It is economical, is easily available, and efficiently compares tooth color with a standardized reference shade guide.[3] The currently available tooth shade tabs are Vita Lumina, Vita classical-three-dimensional (3D) master (Vita), Portrait IPN shade guide (Dentsply), Vintage shade guide (Shofu), and IPS e. max shade determination (Ivoclar vivadent).[4] The selection of the tooth color by the shade tab method completely depends on the human eye observation. The human eye detects the color difference intraorally under standardized conditions (3.7 Δ E unit).[5] The variables of the visual shade guide method are a subjective variable and a physical variable. The subjective variable is the clinician variability of experience, age, eye fatigue, judgment mood, emotional shifts, illusions, and color blindness.[6] The physical variables are extreme light conditions, type and intensity of light source, angle of incidence, tooth texture (contour), the color of the wall, and clothes worn by the patient and staff.[7] The tooth color selection by the Vita 3D master shade guide is the most commonly used among the commercially available shade tabs. It gives superior and standardized color difference (ΔE = 5). It significantly improves the repeatability of shade-matching procedure in the hand of the young dentists. The significant difference between the Vita classic and Vita 3D master is that the Vita classic is based on the hue of the color and Vita 3D master determines the value of the color.[7,8] Regarding gender difference, females achieved significantly better shade matching than males.[9]

The instrumental method of color evaluation significantly reduces the subjective errors of the human shade visualization. Device that are used to determine tooth color are Spectroshade (spectrophotometer, MHT Optic Research AG, Niederhasli, Switzerland), ShadeVision (digital camera with colorimeter, X-Rite America, Inc., Grand Rapids, Michigan, USA), Vita easyshade (spectrophotometer, Vident, Brea, CA, USA), and ShadeScan (digital camera with colorimeter, Cynovad, Montreal, Canada).[10] The Spectroshade is a calibrated device that records two images which overlap with each other for better comparison. If the color difference of the two images is <1.00, then the image will be saved and if it is >1.00, then the image will be deleted. The ShadeVision is a calibrated device that measures the target shade with a light glare at the junction of the gingival and middle third. The shades will be selected from a database of CIE L*a*b* values. The Vita Easyshade is a calibrated device that records the consecutive readings generated by the device. The probe of the device will be held at 90° middle one-third of the selected tooth. The Shadescan records light glare directed at the mesiobuccal and distal buccal-line angle in the middle third of the tooth.[10] There are few modified devices that record the tooth image by modifying the intraoral camera or using the high-resolution camera (Nikon, Japan) and further transfer to the computer with an integrated software. The computer tooth image has more clarity, thus it reduces many subjective errors of visual shade guide method.[11,12] Recently, mobile application was evaluated for color matching, however the accuracy was inferior to that of Vita classical shade tab.[13]

There is a three-color system that provides the baseline values for color experiments. The Munsell color order system consists of a number of colored chips for visual color matching, arranged in the following three dimensions of appearance: value (V), hue (H), and chroma (C). The CIELAB color space (also known as CIE L*a*b*) expresses color as the following three values: L* for the lightness and it correlates to value (V) in the Munsell color system, a* for green (−) to red (+), and b* for blue (−) to yellow (+). It defines the color properties independently of a established image. The CIELAB color space is typically used when graphics for print have to be converted from red green blue (RGB) to CMYK color models. The CIELCH is one more color space, in that C* specifies chroma and h^0 denotes hue angle, for angular measurement. The advantage of the CIELCH color system over the CIELAB in that it is easy to relate physical samples based on the Munsell color scale.[14,15]

In the instrumental group, the Vita easy shade (VES) spectrophotometer demonstrated the greatest accuracy and more reproducibility than human shade assessment.[16] Colorimeter device is designed to measure color (hue, chroma, and value) as perceived by the human eye. Certain devices that acquire red, green, and blue image information to create a color image (digital cameras) are commonly referred to as RGB devices. The information accuracy of RGB devices is questionable as they do not measure the instrument reading, rather they define the color proprieties of a captured image.[17] The colorimeter instruments (Shadescan and Digital image recording devices) are technique sensitive and thus there will be a high probability of less accurate reading of tooth image in the hand of an inexperienced operator. Nevertheless, a well-designed colorimeter will give the

acceptable results,[17,18] for example, X-Rite's ShadeVision system.

The most significant disadvantage of an instrumental method is the cost of the instrument as every dentist cannot afford the cost of the equipment, particularly in developing countries like India. However, a visual shade guide can give a more accurate result that is closer to a spectrophotometer or a colorimeter, provided that clinicians must acquire proper training and knowledge of the shade selection protocol. The purpose of writing this systematic analysis is to evaluate various measures for tooth shade selection, to analyze the advantages and disadvantages of the various tooth shade selection methods, and to find out more efficient and economical way of tooth shade selection method of the natural tooth color.

MATERIALS AND METHODS

This systematic review was designed according to the guidelines of the Preferred Reporting Item for Systematic Review and meta-analysis guidelines.[19,20]

Search strategy

A systematic search was conducted from January 2002 to December 2018. The search strategy was based on PICOS framework [Table 1] Peer-reviewed journal articles were identified using the following electronic database: PubMed (www.ncbi.nlm.nih.gov), ScienceDirect (www.sciencedirect.com), Google Scholar (http://sholar.google.com), and Cochrane Library Web of Science. Keywords used were "tooth shade;" "natural tooth shade;" "shade selection;" "prosthodontics;" "conventional and instrument shade selection;" 'digital image shade selection;" "spectrophotometer shade selection;" and "colorimeter shade selection." Related articles were identified from the existing reviews and study design (networking meta-analysis) PICOS framework [Table 1].

Inclusion and exclusion criteria

The two reviewers had examined the articles independently to decide whether the articles met the inclusion criteria.

Table 1: PICOS Question for the study

PICOS	
P: Participants	Shade selection of esthetic zone
I: Intervention	Different shade selection method
C: Comparison	Visual shade guide, colorimeter, reflectance spectrophotometer, shade selection software, digital camera image processing
O: Outcome	Digital shade selection is better than conventional method
S: Study design	Networking meta-analysis

Inclusion criteria:

1. Studies including peer-based articles published from January 2002 to December 2018
2. Studies that discussed the tooth color properties
3. Studies including the comparative evaluation of shade matching by various conventional methods
4. Studies including the comparative evaluation of shade matching by different instrumental methods
5. Studies that discussed factors affecting a tooth shade selection
6. Studies that discuss a comparative evaluation of a visual shade method and instrumental shade method.

Quality assessment

The two authors have performed a quality assessment using the Cochrane Collaboration tool for assessing the risk of bias. All the selected articles were assessed by the first and second authors. The studies were evaluated using the domains (viz., random sequence generation, allocation concealment, blinding of the participant and personnel, blinding of the outcome assessment, incomplete outcome data, selective outcome reporting, and other bias). The studies were rated further as a risk of bias (low, medium, and high) by the investigators.

Data management and statistical analysis

Data were extracted independently by two reviewers using a specific format. Specific important information included year of publication, natural tooth shade, conventional shade selection, digital shade selection, all-ceramic crowns, metal-ceramic crowns, and spectrophotometer.

Tools used for measuring outcomes were categorized as shade assessment: natural tooth shade, conventional shade matching, digital shade matching; comparative evaluation: conventional and digital shade matching; and instruments for matching: spectrophotometer, colorimeter, scanner, and computer software.

The outcomes were presented for relevant studies in a graphical format where possible. The studies were graphed according to the mean differences (MDs) with the level of significance set at $P < 0.01$. In the meta-analysis, heterogeneity was measured as a final calculation of effect size and the confidence interval (CI) around that effect size by using a random effect and fixed-effect model in the forest plot.

RESULTS

A total of 1573 records were identified through database search (PubMed, Medline, Google Scholar, and

EMBASE), out of which 1383 records were excluded as they were irrelevant or data units were not unavailable, or due to repetition. The remaining 190 full-text articles were assessed for eligibility, out of which 34 articles were excluded due to the following reasons: not relevant data on shade selection method, articles not in English, and articles without anterior teeth shade selection. The remaining 156 articles were selected, out of which 38 articles were selected based on the keywords such as "tooth shade;" "natural tooth shade;" "shade selection;" "prosthodontics;" "conventional and instrument shade selection;" "digital image shade selection;" "spectrophotometer shade selection;" and "colorimeter shade selection." Seventeen full-text articles were excluded for the following reasons: values of interest presented with different units, hence cannot be compared (11) and studies with no units (6) [Figure 1]. Thus, finally, 21 studies were included in the present systematic review and meta-analysis [Figure 2].

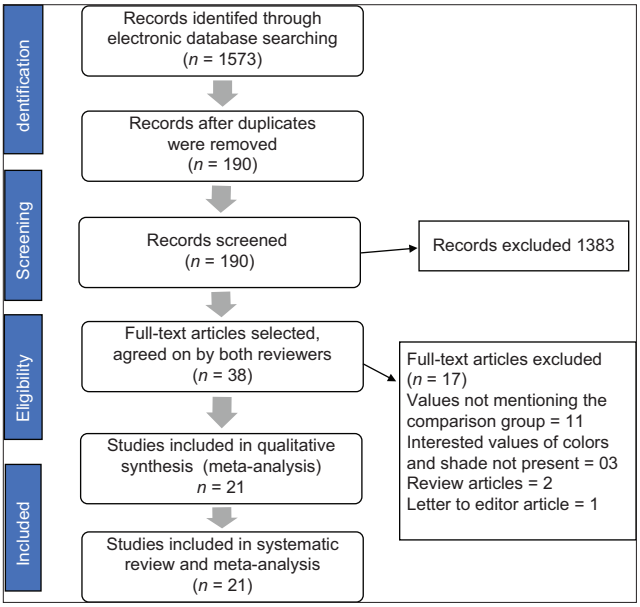

Figure 1: PRISMA flowchart for study selection

Risk-of-bias assessment

There are 21 studies on tooth color analysis. Out of the 21 studies, there are 8 cross-sectional, 6 comparative, 5 randomized controlled trials (RCTs), and 2 *in vitro* studies. The comparative studies evaluated the comparison between the visual shade methods and instrumental shade methods. The hypothesis of the comparative study reported that instrumental method, particularly VES spectrophotometer, is more accurate, reliable, and repeatable in shade selection, as it eliminates the subjective errors of the visual method. There is a significant risk of performance and outcome bias with comparative studies as the VES spectrophotometer was used for comparison with the multiple shade guides. It is difficult to find out the baseline values for other device and the baseline values for various shade guides that introduced a significant risk of outcome bias. However, there is one comparative study which reported greater value for the Vita-3D master. The cross-sectional studies reported the observation of dental students (1st year, 3rd year, and the interns), nondental population, and dentists. The cross-sectional studies also found the significance of knowledge and training of shade method protocol. The significant risk of bias of the observational studies is performance bias as the observation of natural tooth color or observation of the shade guide does not verify the outcome irrespective of proper training of shade matching as there are various subjective variables of shade selection. However, proper training, knowledge, and clinician

C3	Mean Difference	Standard Error	95.0% Lower Confidence Limit	95.0% Upper Confidence Limit	Percent Random Effects Weight	Percent Fixed Effects Weight
2002	-1.0600	0.3679	-1.8135	-0.3065	7.1325	0.3406
2003	-1.5000	3.5046	-8.5948	5.5948	0.4990	0.0038
2005	18.1000	5.8651	5.7780	30.4220	0.1853	0.0013
2009	-1.9400	0.6634	-3.2429	-0.6371	5.3486	0.1047
2009	-3.4500	0.2014	-3.8530	-3.0470	7.9576	1.1358
2011	-0.8000	0.1319	-1.0585	-0.5415	8.1894	2.6489
2012	1.3600	1.2205	-1.2577	3.9777	2.8737	0.0309
2012	-0.1000	0.4061	-0.9057	0.7057	6.9089	0.2795
2012	1.0000	1.6273	-2.1992	4.1992	1.9020	0.0174
2013	-0.3000	0.5200	-1.3434	0.7434	6.2142	0.1705
2014	45.0000	2.4452	40.1787	49.8213	0.9645	0.0077
2015	-0.5000	1.0945	-3.0881	2.0881	3.2977	0.0385
2015	-9.4000	1.3688	-12.5564	-6.2436	2.4576	0.0246
2016	-0.1100	0.0337	-0.1779	-0.0421	8.3602	40.7061
2016	-1.7300	0.2629	-2.2504	-1.2096	7.6896	0.6668
2016	0.0500	0.0311	-0.0117	0.1117	8.3620	47.6848
2016	-2.4100	0.6834	-3.8056	-1.0144	5.2331	0.0987
2017	4.5500	0.3304	3.8956	5.2044	7.3425	0.4221
2017	-0.3100	0.0906	-0.4884	-0.1316	8.2850	5.6111
2017	19.3300	3.1097	13.0348	25.6252	0.6238	0.0048
2018	13.4600	6.0765	-0.5524	27.4724	0.1729	0.0012

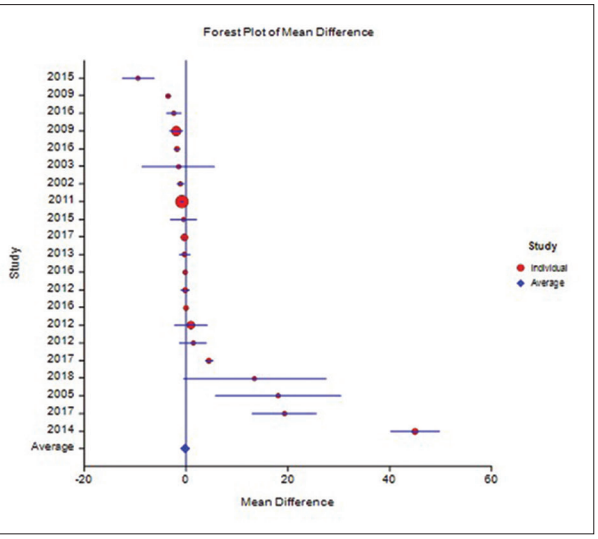

Figure 2: Forest plot of fixed-effect model and randomized effect model

experience will definitely affect the final shade matching. The RCT evaluated the repetitive observation of the shade guides by masking the original shade guide by proper tape or randomly divided the participants into various groups. The RCT reported significant attrition bias due to repetitive observation of the same shade.

Meta-analysis

The meta-analysis was performed by combining the results of the 21 studies, which included various tooth shade selection methods. A random-effects model and a fixed-effects model were used. The homogeneity test confirmed acceptable heterogeneity among the studies (I^2 = 98%) [Figures 2-4].

The result of tooth shade selection methods reported statistically significant heterogeneity (Q = 1038.1518, df = 20, and $P < 0.0001$). The statistics of fixed-effect model reported an MD of −0.0970 (95% CI = −0.1391, −0.0549). The random-effect model reported an MD of − 0.0862 (95% CI = −0.5866, 0.4142), which indicates a statistically significant difference between the treatment and control groups.

The meta-analysis reported a significant color difference between the instrumental method and visual method of tooth shade selection. VES spectrophotometer demonstrated significant color difference than other devices used for tooth color selection, and Vita 3D master showed highly significant values for color difference than the Vita classical and other shade guides from different manufacturers.

DISCUSSION

The purpose of the meta-analysis is to evaluate various measures for tooth shade selection, to analyze the advantages and disadvantages of the various tooth shade selection methods, and to find out a more efficient and economical way for tooth shade selection. The review combined the results of 21 studies and synthesized the following information [Table 2].

The comparative studies reported the comparison of a spectrophotometer and visual tooth shade guide methods. The spectrophotometer serves as more accurate, repeatable, and reliable method as there is no subjective errors with easy shade spectrophotometer. The Bahannan[21] proposed that the VES spectrophotometer produces 80.4% of correct shade matches than the 36.3% of shade matches produces by visual shade guide. The instrumental shade matching by VES spectrophotometer was more accurate than the vita-classical shade guide (Vita Zahnfabrik GmbH, Bad Sackingen, Germany). There was higher accuracy of VES (52%) compared to that of the visual shade guide (34%).[22] The precise knowledge of shade selection and gender difference suggested that females have significantly better impact of shade selection in relation to lightness, Hue, Chroma, and shade-matching score.[9] However, knowledge of shade selection has minimal influence on shade selection.[9] The comparison of tooth shade selection by trained and untrained dentists reported the similar observation about spectrophotometer, but the knowledge and training on color science and shade selection significantly impact on the final result of esthetics as it improved the shade-matching ability of trained dentists (ΔE = 3.45 for a trained dentist than ΔE = 4.98 for an untrained dentist).[23] Paul *et al.* reported that spectrophotometer analysis produces more accurate results than the visual method when a comparison was made on 14 male and 16 female patients in the age group of 17–44 years. The significant findings of the study suggested that human observes the color difference of 1 ΔE under standardized laboratory conditions. However,

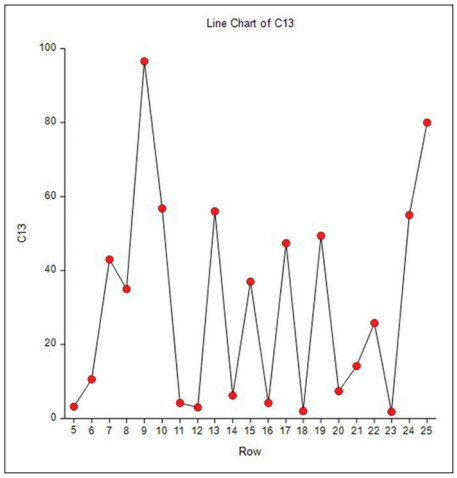

Figure 3: Standardized mean difference

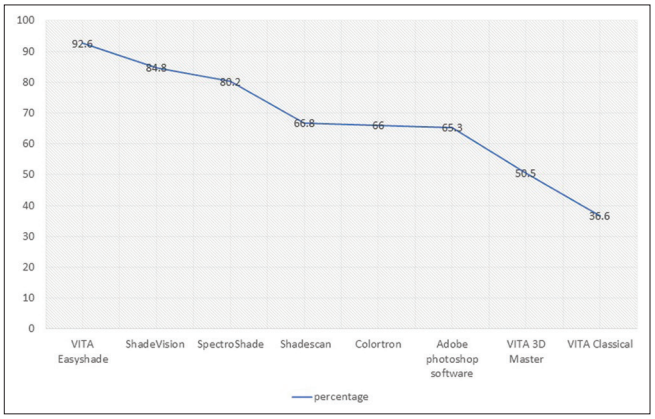

Figure 4: Accuracy-wise distribution of shade-matching process

Table 2: Studies of shade selection methods

Author/year	Type of study	Type of intervention	Primary end point	Outcome
S. Paul *et al*. (2002)	Comparative study	Visual shade selection and instrumental shade selection (spectrophotometer)	The mean ΔE=3.15±1.08 for visual shade and the mean ΔE=2.099±0.94 for spectrophotometer (P<0.0001)	Spectrophotometer analysis is highly significant and more reproducible
Dancy *et al*. (2003)	Randomized controlled trial	Digital imaging of shade before and at the time of cementation of ceramic crown	The clinical significance of the study reported that photocolorimetric method can serve as reliable alternative to visual shade guide method for clinician who have difficulty with shade selection	The operator agreement does not show any significant difference for tooth shade selection between conventional method and photocolorimetric method
J.D. Jarad *et al*. (2005)	Cross-sectional	Digital and computerized matching method	A total of 540 observations and 61.4% correct matching by computer method than 43% match by visual method	Computer method is better than visual but not accurate than spectrophotometer
Bona AD *et al*. (2009)	Comparative study	Observation and comparison of shade selection by three different population (GP, DS, and DD) under CWF light and NSL by using VC and Vita-3D	Intraexaminer agreement (k=0.76). PVIA recorded for GP was 35.2% for VC and 22.0% for 3D. The PVIA for DS was 32.2% for VC and 17.5% for 3D and DD reported 41% PVIA for both VC and 3D	Shade training and dental experience are important components in shade matching
Pusateri SK *et al*. (2009)	*In vitro*	Comparison of instrumental shade device: shade vision, Spectroshade, Vita easy shade, and Shade scan	Interdevice variability's accuracy is 67%-93% and reliability is over 96%. The highest accuracy was recorded (92.6%) for Vita easy and lowest for Shade scan (66.8%)	Vita easy shade spectrophotometer reported high accuracy
Yilmaz B *et al*. (2011)	Cross-sectional	Visual matching by 13 male and 22 female dentists	The percentages of shade determinations with two different arrangements of Vita classical shade guide reported the accuracy of 58%. However, the shade accuracy as per the hue and chroma was 55.5% in hue and chroma and 54.3% shade accuracy was according to the value	No significant difference was observed by the difference on repetitive measurements
Alsaleh S *et al*. (2012)	Comparative study	Self-shade matching ability by dental student on visual and instrumental methods	Significant difference in color selection by visual and instrumental methods	Instrumental is better
Khashayar G (2012)	Cross-sectional	Comparison of two spectrophotometers	Two different spectrophotometers do not give similar readings	Dentist and dental technician should use the same device for better comparison
Rodrigues S *et al*. (2012)	Cross-sectional	Shade difference as per the age group	Shade evaluation in younger age as well as in advanced age	Different shade appearance in both age groups (mentioned in discussion)
Ozat PB *et al*. (2013)	Randomized controlled trial	Repeatability and reliability of human eye in visual shade	Repetitive shade selection by the groups of dentist on various individuals reported inconsistency in shade selection (P=0.000)	To get clinically acceptable shade knowledge and training is essential for accurate shade matching
Bahannan SA (2014)	Comparative study	Shade quality evaluated by dental students	36.3% of the dental students accurately recorded visual shade and 80.4% recorded easy shade	Spectrophotometer improves the quality of shade matching
Alshiddi IF *et al*. (2015)	Comparative study	Visual and spectrophotometer shade evaluation by untrained and trained dental students	There is a significant color difference between spectrophotometer (average ΔE=3.63) and visual method (average ΔE=4.22) at (P<0.025)	Spectrophotometer showed better result, but the knowledge of the shade selection is more important than the device
Dudea D *et al*. (2015)	Cross-sectional	Five (gray, white, black, red, and blue) background effect on shade matching	Statistically significant difference in all the five backgrounds (χ^2 (4)=12.67, P=0.01) and for blue background (U=107.00, Z=2.52, P=0.01. Mann-Whitney test)	The blue backgrounds introduced maximum distraction for visual shade matching
Lee YK (2016)	Cross-sectional	The color selection of missing teeth	Maxillary incisor showed high color difference (L*=−3.2-−6.5, a*=0.5-2.7, and b*-−0.7-7.5) (P<0.0001)	Mandibular anterior teeth were strong predictors for missing maxillary anterior teeth
Gurrea J *et al*. (2016)	*In vitro*	Cross-polarized photography evaluated the shade tabs	Four different shade tabs showed variable results for hue, Chroma, and value (P=0.05)	None of Vita coded shade tabs showed complete correspondence with the actual Vita shade tabs
Clary JA *et al*. (2016)	Randomized controlled trial	Visual filters lights, education, and training for shade matching	The mean score for handheld light is 7.8. The combined effect range of handheld light, education training of shade matching is 1.2-6.8 than the viewing booth (8.0)	Handheld light is alternative to natural day light for visual shade selection. The training about shade selection improves the shade-matching ability of the clinician

Contd...

Table 2: Contd...

Author/year	Type of study	Type of intervention	Primary end point	Outcome
Pohlen B *et al*. (2016)	Comparative study	Tooth shade-matching ability and different color knowledge by giving 60 min lecture of color science on 16 male and 16 female participants	Female participants select better color select than male participants (L*=12.11 for FL, L*=11 for MNL. C*=9.86, for FL and C*=8.57 for MNL)	Gender has more significance than knowledge of the shade
Alfouzan AF *et al*. (2017)	Randomized controlled trial	Color training of the dental students	There is a statistically significant difference in pre- and posttraining results (f=39.340. P<0.001)	Shade training is more significant for dental student
Chitrarsu *et al*. (2017)	Randomized controlled trial	Digital and spectrophotometer with addition of LED or filtered LED	The result was significant for daylight, incandescent light, LED light, and filtered LED light (P<0.05)	Incandescent light showed more accurate shade matching than the LED light, filtered LED light, and day light
Igiel *et al*. (2017)	Cross-sectional	Model evaluation of shade matching by forty observers	The inter-observation reliability was 64 (11) for Vita classical and 48 (10) for Vita 3D. The corresponding values for spectrophotometer was 96 (4) for both VC and 3D	Spectrophotometer is highly significant. Visual shade matching exhibited a high-to-moderate level of incompetency
Kim M *et al*. (2018)	Cross-sectional	Digital shade matching with SVMA evaluated Vita-3D master shade guide (10 measurements)	SVMA reported 90% matching accuracy and less than 1% failure rate achieved for 10 measurements	SVM measurement may be an optimum solution for quantitative measurement of tooth color

DS: Dental student, Gp: General population, DD: Dentist, CWF: Cool white fluorescent, NSL: Natural sunlight, VC: Vital classical, SVM: Support vector machine, SVMA: SVM algorithm, PVIA: Percent visual instrumental shade agreement, LED: Light-emitting diode, 3D: Three-dimensional, MNL: Males that did not listen, FL: Females that listened

the same observation in the oral cavity is 3.7 ΔE when matched for the compared tooth and that is the significant reason for the standardization of spectrophotometer.[5] The color difference value for spectrophotometer is 0.48 ΔE. The other properties of spectrophotometer that improve the accuracy include the scattering absorption from the spectrophotometer on the tooth, depth-dependent translucency, and closest match of the reading from a tooth to the data of the color library result in the shade chosen by the spectrophotometer. Paul *et al*. explained the spectrophotometer accuracy 33% more than the human eye, and it increases up to 93.3% in a close match to the tooth.[5] In the visual shade guide, the Vitapan 3D-master shade guide system reported superior shade-matching results and a more standardized color difference (ΔE = 5) than other shade guides. The 3D shade guide has improved conventional shade matching, more ordered color distribution, and higher color match than other shade tabs. The Vita classical shade tabs reported the uneven distribution of color space relevant to human teeth.[6] *In vitro* comparison of different shade guides by using the digital camera cross-polarized photography of different shade tabs (Vita classical [control]) combined with cross-polarizing filter reported that A2 shade homogeneity among all shade tabs and A1, A3, and A3.5 of Vita classical showed the lowest value.[4] The comparison of electronic shade-matching instrument (SpectroShade, Shadescan, Vita easyshade, and Shadevision) reported that all the devices have the reliability ranging from 87.4% to 99.0%. All the devices recorded predictable shade value (variability 67%–93%) by repeated measurements. However, Vita easyshade recorded the highest accuracy and ShadeVision recorded the lowest accuracy.[10]

The observation studies reported the observation between instrumental shade guide and visual shade guided. Most of the studies showed homogeneous results with varying interventions. Jarad *et al*.[12] observed computer-based shade matching and suggested that it enhances the clinician's ability to match the tooth color in a difficult situation when the clinician is unable to evaluate a single shade tab to match the tooth. The computer shade matching recorded 61.1% correct shade matching than 41% correct shade matching by a conventional method ($P < 0.001$ and $P < 0.04$ for the conventional and computer methods, respectively).[12] Kim *et al*.[11] developed the method of digital shade by modifying the intraoral camera. The two linear polarizer were placed in front of the light source (cross-polarization) of an intraoral camera which blocks the light from outside. These modified devices use the Vita-3D shade guide for color determination along with a support vector machine algorithm (SVMA). The author observed that this method helps in the quantitative measurement of tooth color with high accuracy. They further stated that spectrophotometer and colorimeters do not provide true image information to measure the exact value of tooth color.[11] A cross-sectional study on 400 individuals reported that the most common shade of maxillary and mandibular incisors in younger age male is A2 for Vita Lumina, 2R2.5 for Vita 3D master, and 140 for Chromascop shade guide and for females is A1 for Vita Lumina, 1M2 for Vita 3D master, and 120 for Chromascop shade guide. In the advanced age

group, the most common shade for the same teeth is A2 for Vita Lumina, 2R2.5 for Vita 3D master, and 140 for Chromascop shade guide. Males have darker teeth than females.[24] The color values (L*a*b*) recorded by two different spectrophotometers do not show similarities; this means the dentist and dental laboratory technician should use a similar method or device of tooth shade selection for better tooth shade matching.[25] The background/surrounding is the significant physical error of visual shade method and the reported error produces by blue background ($U = 107.00$, $Z = -2.52$, $P = 0.01$) has significantly affect the shade quality of visual shade method, particularly the shade group of A 3.5, B3, B4 and D4.[26] The observation of the visual shade guide (Vitapan classical) in relation to hue, chroma, and value reported 55.5% accuracy of shade selection in relation to hue and chroma and 54.3% shade accuracy was significantly influenced by value property of the tooth color.[3] The observation of visual shade guide and instrumental shade method by the general population (no knowledge of shade selection and dental science) reported the higher significance of percent visual instrumental shade agreement (PVIA = 38.5%) for Vita classical shade guide than the Vita 3D Master. Similarly, 1st-year dental students demonstrated higher PVIA (35%) for Vita classical than Vita 3D master and the dentist demonstrated highest PVIA (42%) for the same; however, a small number of dentists reported previous awareness of the 3D shade guide. Hence, the familiarization with the shade-matching processes is significant for the clinician to produce accurate shade for the dental color.[27] The observation and comparison of the missing tooth color showed that for better shade comparison, the selection of the opposing arch but the same type of tooth color would be more appropriate, for example, in case of missing maxillary lateral incisor, selection of the mandibular lateral incisor would be a better match and in case of missing maxillary canine, selection of the mandibular canine color would be a better match.[28]

The RCT evaluated the significance of knowledge and skill of shade selection for accurate shade matching. The RCT of the repeatability and reliability of the human eye in visual shade selection analyzed and reported that there is inconsistency in reliability in visual shade matching on repeated observations (88.9%). However, a clinician can record clinically acceptable shade provided that he or she must follow the protocol provided by the manufacturer.[29] The significant variables associated with natural day light can be best minimized by using the hand held light as it reduces the background distraction and increase focus on shade-matching comparison of the tooth color.[7] The education and training of the color matching significantly improve the shade-matching process.[7] Overall, the study finding suggested that greatest improvement in a shade-matching process occurs when the light was combined with education and training.[7] The shade evaluation was performed at the preparation appointment and at the cementation appointment. The study findings reported that there is no difference in shade selection either by conventional method or photocolorimetric method.[30] The photocolorimetric method of shade selection can serve as a reliable alternative to the conventional method for the clinician who have difficulty with shade selection. The randomized comparison of the effect of a light-emitting diode (LED) versus filtered LED light sources on the intraoral digital spectrophotometer reported that the incandescent light showed more accurate shade matching than the filtered LED.[31] Alfouzan *et al.*[9] suggested that Vita Linarguide 3D-master shade guide gives more accurate shade comparison then vita lumina. However, training of

Table 3: Significance of a different types of tooth shade selection method

Tooth shade selection tool	Shade selection			Operational value	Economical value
	Hue	Value	Chroma		
Spectrophotometer	+++	+++	+++	+++	+
Photocolorimeter	+++	+++	+++	++	+
Digital imaging	+++	++	++	++	+
Scanner (SVMA)	++	++	++	+	+
Cross-polarized photography	++	++	++	+	++
Visual shade guide	++	++	++	+	+++

+++: High value of significance:, ++: Moderate value of significance, +: Low value of significance, SVMA: Support vector machine algorithm

Table 4: The recommended guidelines for visual shade selection procedure

Steps	Preparation
Clinician position	Patient should be seated at an upright position at the elbow level of the clinician. The distance of 25-35 cm (arm length) from the patient to clinician to minimize subjective error of eye fatigue shade should be selected quickly (5-7 s) Squint test (partly close the eye): Increase the value of the shade
Light condition and background	Use color-corrected light illumination and avoid bright color at the working area and if the patient wear bright cloth, cover the patient with gray drape, dark-colored lipstick should be removed before shade selection. Shade selection should be done at forenoon between 10 a.m. and 2 p.m. To reduce the background light, use 18% gray card (Kulzer's small intraoral gray cardboards, Pensler shields screen)
Shade comparison	The selected tooth should be clean with Prophy paste, shade should be selected before tooth preparation as dehydration reduces the translucency of the tooth, the selected shade tab should be viewed from above or below the tooth to match and not adjacent to the selected tooth (binocular effect) Hold the shade tab at the incisal edge of the tooth to be matched to minimize the reflection of the adjacent tooth. The selected should tab should be viewed from different angles (vectoring)

the dental student for tooth color science is the valuable step for shade matching quality.

Summary of the evidence and recommendation:

The meta-analysis evaluated 21 articles for tooth shade selection, which included a visual method and instrumental method. The instrumental method consisted of spectrophotometer, photocolorimeter, digital imaging, scanner (SVMA), and cross-polarized photography [Tables 3 and 4]. The VES spectrophotometer is more accurate, reliable, and repeatable in shade evaluation than other devices and visual system used for shade selection. The VES reduces the subjective errors of color difference of a visual method. The most significant advantage of Vita Easy shade (VES) spectrophotometer is to reduce the subjective error of visual shade method as VES Spectrophotometer detect the color difference of 1 ΔE, whereas human eye detects the color difference of 3.7 ΔE. Photocolorimeter produces better shade matching but it is not superior to VES, and the device is technique sensitive, so any error during shade-matching procedure will affect the final result. The digital imaging, SVMA, and cross-polarized photography need further evaluation irrespective of an adequate result than visual method as there is no standardization and it is not convenient as chairside procedure. The main problem of the instrumental method is the cost of the device that every dentist cannot afford the cost of the device.

The visual shade matching is a routinely used method for shade selection as a chairside procedure. It is convenient, economical, quick, and easily available. The significant subjective and physical errors by visual shade matching minimized the quality of the final shade. However, Vita 3D master produces more reliable and consistence result of shade matching than the vital lumina and other shade guides of different manufacturers. The clinical experience, knowledge, and training of the shade-matching protocol definitely improve the shade-matching capability of a clinician.

The recommendation of the review is that the visual shade guide may give acceptable clinical shade matching provided that the subjective and physical errors should be majorly reduced if they cannot be eliminated completely. The knowledge and training of shade-matching protocol as continuing dental education are essential for clinicians to improve the quality of shade matching. Shade selection should always be done before tooth preparation as the hydrated tooth always show better enamel translucency. The tooth shade selection should always be carried out from 10 a.m. to 2 p.m. as the color temperature during this period is around 5500 k that enhances the accuracy of shade matching. The selected shade should be evaluated at the different angles of the matched tooth as the presence of minute roughness on the tooth reflects the different wavelengths at the different directions, and the textured appearance such as presence of matte appearance and luster (heavy, moderate, and light) appearance should be mentioned in the work authorization form to the laboratory technician as these surface features determine the percentage of opacity (light reflection and amount of light that enters the tooth). Eventually, the clinician who has the difficulty during visual shade selection due to age, color blindness, or any eye problem can go for the instrumental method, more particularly the VES spectrophotometer.

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Conflicts of interest

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