Systematic Analysis on Accuracy of Aids Used in Color Selection in Prosthodontics

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Abstract: *Dentist today not only restored the teeth patients nowadays have become more aware in improving the aesthetics and there proper functioning. Visual shade matching in daily clinical practice is still a challenging procedure for dental professionals due to the subjectivity of the process. It also needs advanced training, failing which may result in unsatisfactory results for both patients and the clinician. Therefore instrumental methods were introduced to simply this procedure and to provide better aesthetic outcome so in this study witch instrument to be found one of the best methods for shade selection.*

Keywords: Natural light, Synthetic light, incandescent light, fluorescent light, full spectrum light

1. Introduction

Exactly matching natural teeth with an artificial restoration is one of the most challenging procedures in restorative dentistry. Natural teeth vary greatly in color and shape for every patient. They reveal the personality of the patient[1]. Whether one tooth or many is restored, the ability to assess the accurate shade as such of the natural teeth properly can be greatly improved by learning the characteristics of color and light[2] Many factors influence the perception of tooth color such as incident light, the reflection and absorption of light by the tooth, the perception state of the observer, and the manner in which the tooth is viewed[3]. There are various methods to select shades, including the use of shade guide colorimeter, spectrophotometer, computer software and digital photos [3]. The conventional method was by visually selecting the shade by the naked eye using the commercially available shade guides. But it is impossible to replicate the exact objective colour of the natural tooth. Therefore the use of colour measurement devices, such as colorimeter and spectrophotometer is gaining popularity in dentistry as they can provide us with better results of shade selection by acquiring quantitative shade information for a specific narrow region[4][2]. Recently, mega pixels digital cameras are widely used for shade selection. Despite of providing good image information by digital colour imaging modality, it has a drawback of specular reflection caused by saliva or roughness on the tooth surface might cause in image analysis [5][6]. Of the above mentioned methods; spectrophotometer is said to be the most accurate method for giving best aesthetics. The purpose of this article is to compare all the results of the above mentioned methods of shade selection and to analyse the most accurate method of shade selection that gives the best aesthetics and patient satisfaction.

2. Materials and Methods

Search Methodology:

Inclusion criteria

a) Studies related to conventional shade matching.
b) Articles related to digital photographic shade matching.

c) Study design includes randomized control study, cohort study, clinical study, cross sectional studies, Meta - analysis
d) Only past 10 years studies.
e) Only human studies.
f) Studies in English language.

Exclusion criteria

a) Studies using restored teeth, non-vital teeth.
b) Articles published in other languages
c) Full text articles that were not available on the database search.

Figure 2: Search strategy

The data obtained was charted in the tabular column using PICO format.

S.N	Reference	Study Design	Setting	Method	Device	Sample Type	Sample Number of teeth	Sample Area	Assessment
1	Mohammadreza Nakhae	Cross sectional	In vivo	Visual Spectrophotometer	3D master shade Vita easy shade	Natural teeth		Middle third	Spectrophotometer photography would increase the predictability for aesthetic dental restorations.
2	Punith Rs – Khuranan	Randomized control trial	In vivo	Visual Spectrophotometer	3D master shade guide Vita easy shade guide	Natural teeth	1640		Combination of visual and digital shade analysis gives a precise predictability of shade
3	Motaz Ahamed Ghullman	Randomized clinical trial	In vivo	Visual Spectrophotometer	Chromoscope shade guide Spectrometer	Natural teeth	3758	Middle-third	Spectrophotometric shade analysis seems to be more reproducible than visual shade determination
4	Kivanc Yamanel		In vitro	Visual Colorimeter	Vita Lumin Vita 3D Shade eye	Natural teeth	4		Digital colorimeter may be in advantage over traditional method
5	Jin –Cheol Kim		In vivo	Visual	Vita 3D	Natural teeth	54	Labial surface	Dentists can match clinically acceptable shades in visual methods
6	Burakyilmaz, Lalekaraagaclioglu	Cross sectional	In vitro	Colorimeter	Shade guide , colorimeter	Shade tab	25		Colour replication of metal ceramic specimens using visual shade determination was more accurate compared to instrumental shade determination.
7	COLIC B – PREJMEREAN		in vivo	Spectrophotometer colorimeter	Easy shade Shade pilot Shade vision	Natural teeth	15	Cervical Body Incisial	Clinically acceptable intra device repeatability for all tooth regions when using same colour measuring device
8	Stepan J .Chu		In vivo	Visual Spectrophotometer	Vita C Vita easy shade	Shade tab Natural teeth	9 9	Middle 3rd	Spectrophotometer was more likely to match color than the visual method
9	Karl Martin Lehmann		In vivo	Spectrophotometer colorimeter	Easy shade Shades	Extracted natural teeth	25	Middle 3rd	Easy shade systems were most reliable
10	Radtigo Tisssi			Visual Colorimeter	Vintage halo shade guide Shad guide NCC colorimeter	Natural teeth	20	Middle 3rd	Shade eye NCC Chroma meter make better results
11	Malvin N Janal		Model	Visual Graphic computer software	SAHADE GUIDE	Shade tab	12	Labial surface	Better performance by graphic computer than by visual shade matching
12	Mohamohammadrezanakaei		In vivo	Visual Spectro radiometer	Vita lumin Vitapan 3D Vintage halo Vintage halo NCC Chromoscope	Natural teeth	60	Middle 3rd	Vitapan 3D Master was the suitable one among the other five in shade matching
13	W.D. Browning Et	Randomized control trial	In vivo	Visual Spectrophotometer	Vita bad sacking Easy shade	Natural teeth	1500		Both were similar in accuracy in shade determination
14	Siegbertwitkowski		In vitro	Digital camera Spectrophotometer	Nikon D90 Vita easy shade	Extracted natural teeth	20		Digital camera can be used as an alternative to spectrophotometer as both values were similar
15	Samar Alsaleh Et Al 2012		In vivo	Visual Spectrophotometer	Vita classical Vita easy shade	Natural teeth	50	Middle 3rd	Instrumental shade assessment had a better ability to select the closest shade compared to visual
16	Won Suk Oh Et Al 2010		In vitro In vivo	Digital photo colorimetric	Eye one match	Shade tabs Natural teeth	32 96	Middle 3rd	Shade matching using digital PCM was valid with the use of Vitapan classical shade guide
17	Welsonpimental Et Al 2014	Randomized control trial	In vivo	Visual Spectrophotometer	Vita classical Spectrometer shade guide	Natural teeth	30	Middle 3rd	Instrumental method was more reliable compared to visual
18	DS Moodley Et Al	Randomized control trial	In vivo	Visual Spectrophotometer	Vita classical Vita 3D Spectro photo meter shade	Natural teeth	25	Middle 3rd	Difference in Shade assessment using visual shade guides and spectrophotometer were within clinically acceptable limits.
19	K Yuan Et Al 2012		In vitro In vivo	Computer aided shade matching	Shade pilot Easyshade Shade eye NCC	Shade tabs Natural teeth	80 85	Central region	Shade pilot showed high accuracy and reliability
20	Burakyilmaz Et Al 2011	Randomized control trial		Visual Colorimeter	Vita classical Shade eye NCC	Shade tabs	25		Visual shade determination yielded

								better color replication of metal ceramic specimens than instrumental Shade determination.
21	B. Yilmaz Et Al 2008		In vivo	Visual Colorimeter	Vitapan classical Shade eye N CC	Natural teeth	10	Middle 3rd	The intra-oral dental colorimeter produced acceptable repeatability from the readings of natural tooth.
22	Siegbertwitkowski Et Al 2010		In vivo	Spectrophotometer	Crystal eye	Natural teeth	15		Spectrophotometer was accurate and reliable in shade selection
23	Ana Todorovic Et Al 2013	Randomized control trial	In vitro	Visual Spectrophotometer	Vita 3D Vita classical Vita easyshade	Shade tabs		Middle 3rd	Instrumental shade matching showed better results compared to visual
24	W.K. Tam Et Al 2012		In vitro	Digital camera	Canon EOS 1100 D	Shade tabs	26		Digital camera can be used as a tool for dental shade matching
25	Constanzeolms Et Al 2013	Clinical study	In vivo	Spectrophotometer Visual	Vita easy shade Vitapan classical	Ceramic crown	25		Spectrophotometer was reliable in shade determination
26	Seungyeekim-Pusatira Et Al 2009	Randomized control trial	In vitro	Spectrophotometer	Spectrometer shade Shade vision Vita easyshade Guide	Shade tabs	62	Middle 3rd	All the devices had good repeatability
27	W.D. Browning Et Al 2009		In vivo	Spectrophotometer Visual	Vita easy shade Vitapan 3D	Natural teeth	95	Middle 3rd	Spectrophotometer showed better results
28	Salma A. Bahannan 2014			Visual Spectrophotometer	Vita 3D Vita easy shade	Shade tab	204		Spectrophotometer was better compared to conventional method
29	Alshiddi Et Al 2015		In vivo	Visual Spectrophotometer	Vita 3D Easy shade	Natural teeth	8	Middle 3rd	Shade matching using spectrophotometer is more accurate compared to traditional method
30	Kivancyyamunvel 2010		In vivo	Colorimeter	Shade guide Colorimeter Digital imaging soft ware				Overall, the mean DE values from different composite pairs demonstrated statistically
31	Alvin G Wee	Clinical study	In vitro	Light condition	Ambient light Spectrophotometer		32 private practice		All dental practitioners surveyed used mainly visual shade matching in their practices. Of those, 87.5% showed interest in attending continuing education on this topic,
32	Jianwang		In vitro	Color matching method	Vita pan 3D master Spectrophotometer		29 shade tabs		The DE* values between computer color matching specimens and the target shade tabs varied from 0.5 to 1.9, with an average DE* of 1.3,
33	Degerongul		In vivo	Visual and instrumental method	Vita pan classic Vita 3d master Spectrophotometer	Natural teeth			The selected shades from the Vita Toothguide 3D-Master shade guide were significantly smaller than those of the VitapanClassical guide
34	Mohamohammadrezanakaei		In vitro	Visual shade matching method	Vita pan classic Vita 3d master Spectrophotometer	Natural tooth			No significant among the three Participant groups in delta E
35	Fabianatakatsui		In vitro	AdobePhotoshop soft ware	Vita Luminavacuum EOS canon digital camera AdobePhotoshop	Artificial tooth	80		Values indicate a clinically acceptable difference, suggesting that the independent examiners behaved similarly in obtaining the coordinate values in the automatic mode.
36	Palucadraghici		In vivo	Visual method	Vita 3d master	Natural teeth	102	Left upper central incisor lateral canine	Students showed at a group level relative good ability of visually determining the color of the teeth, by the usage of 3D Master Key. The highest concordance of recordings between the visual and spectrophotometric measurements was observed for hue parameter
37	M Aomari	Randomized control trail	In vitro	Shade guide	Invocalr viva dent Vitapan classic Vita zahnfabrik	Artificial teeth			Hue test was not a good predictor of dental shade matching performance, and (b) both guides performed well in the

									areas of shade they covered, with the Vita Classical guide matching well shades of natural unstained teeth and the IPS guide matching more closely stained/discoloured preparations.
38	Oscar E. Pechoa, B, Razvanghineab, Rodrigo Alessandrettia, María M. Pérezb, Alvaro Della Bonaa, *	Randomise control trail	In vitro	Shade guide,	Spectrophotometer Vita pan classic, vita 3d master	Natural tooth	35 /M 65/F		this study, combining the use of SP, CIEDE2000(2:1:1)and Vita Classical shade guide most closely represented the visual perception of DS.Instrumental shade determination should be accompanied by experienced human visual assessment.
39	Michael Hemming	Randomized control study	In vivo	Intra oral spectrometer	Vita pan classic shade guide Spectrophotometer	Natural teeth	60	Centralincisor, canine	The repeatable of color measurement Was different among the three measuring methods by operators over all the method worked well for both operator
40	Tahirkeraman		vivo	Shade guide	Vitapan classic Spectrophotometer	Natural teeth	202		colour measurements of the maxillary right central, lateral and canine teeth were carried out by the Vita Easyshade
41	Rominaroodgarian		vivo	Shade guide	Vita pan 3d shade guide	Natural teeth	58		Matching scores were computed and the mean of the color differences between the citation shades and the chosen shades counted with formula.
42	*Byeong-Hoon Cho*		Vitro	Hue value Chroma	Colorimeter	Natural teeth	2067		measure the difference in the color and color parameters of natural teeth measured by a colorimeter (CM, used as a reference) and Shade Vision System
43	Project Helene J Haddad		vivo	Shade guide	Vita pan classic Spectrophotometer	Natural teeth	2067		Color difference (ΔE^*min) between each natural tooth and the closest match using two manual shade guides systems
44	Punit Rs Khurana		VITRO	Shade guide Light source	Vitapan 3D master tooth guide system 2. Vitapan 3d master		50	18-30 31-40 41-50	The study was conducted in adult samples of Advancer district origin, randomly selected irrespective of gender. They were grouped into three age groups as follows.
45	Diego Klee De Vasconcellost.		VIVO	SHADE GUIDE LIGHT CONDITION	intraoral spectrophotometer (Vita Easyshade Compact, VITA Zahnfabrik,		33 F 22 M		This study evaluated the influence of ambient light and a D65 standard light source during visual shade matching for natural teeth.
46	Jian Wang, Jin Lin, Mindy Gil, John D. Da Silva, Shigemi Ishikawa-Nagai,	Cross sectional	VITRO	Spectrophotometer	Spectrophotometer	Artificial tooth	21	Shade tabs	Shape and color determine the aesthetics of both natural and restored teeth.
47	Cristina G_Omez-Polo		Vitro	Shade guide	Vita 3d master, spectrometer	Shade guide	26		purposes of this study are to describe the color coordinates of the 26 shade tabs of the 3D Master Toothguide according to their L*, C*, h* coordinates, and to calculate DEab*, DL*, DC*, and Dh* in the 26 shade tabs.
48	Miguel Go´Mez-Polo		vitro	Visual method	Shade guide Spectrophotometer	Natural tooth	1361	Centralincisor	observed a greater correlation between the objective method and the subjective one in the colour dimension of lightness
49	Vidhyaparameswaran		Vitro	Shade guide	Vita pan classic Vita 3d master Spectrophotometer				shade matching abilities of an intraoral spectrophotometer and the

								conventional visual method using two shade guides.
50	Y. N. Wang		Vitro	Shade guide	Vita Lumin Vacuum Vitapan 3D-Master Vintage Halo Chromascop	Natural teeth	30		Colour determination can be performed using two approaches, visual and instrumental. Visual evaluation has proven to be subjective and inconsistent.Therefore a spectroradiometer was used to quantitatively evaluate the colour of the natural teeth and the shade guides.
51	Wd Browning • Dc Chan Js Blalock • Mg Brackett	Randomized control trail	Vivo	Shade guide L	Vitapan Classical Spectro photometer	Natural teeth	3 dentist	upper central incisors	The CIE L*C*H* data captured by the Easyshade guide were the most accurate. The 3D-Master interpolated shades provided by the Easyshade guide were at least as accurate and precise
52	Motaz Ahmed Ghulman, & Mohamed Abdelmageedawad,		vivo	Instumental shade selection	Vita Easyshade spectrophotometer.	Natural tooth	90	Middle third of labial on maxillary central incisior	Reinforcement of ceramics by alumina for In-Ceram and leucite for Empress decreases color production. Level of acceptance between the different ceramic materials and thicknesses varied.
53	Shigemi Ishikawa-Nagai Aki Yoshida Maiko Sakai Joshua Kri		vivo	Instumental shade selection	spectrophotometer.	Natural tooth		6 area of tooth	Mean DE* between contralateral natural teeth was 0.9. Incisal areas of natural teeth exhibited greater differences in color than other compared areas.
54	G Khashayar A Dozic Cj Kleverlan Aj Feilzer		vivo	Instrumental shade selection	Vita Easyshade and Spectrophotometer Shade-Micro)	Natural tooth	102	Cervical, middle, and incisor three upper maxillary anterior.	A statistically significant correlation was found to exist between the spectrophotometer and PDIM for all CIE $L*$, $a*$, and $b*$ color coordinates.
55	Değeröngül, DMD, Phd, Abülentşermet, DMD, Phd, B And Mehmet Cudibalkaya		vitro	Shade guide	Vita pan classic, vita 3d master	Ceramic crowns	33	Maxillary central incisor	The ceramic crowns fabricated with the Vita Toothguide 3D-Master shade guide resulted in a closer Color match to the natural teeth than those of the Vitapan Classical guide.
56	Constanzeolms& Jürgen M. Setz		vitro	Shade guide	Vita easy shade guide	Artificial tooth	25	Ceramic tooth	evaluate the shade stability of tooth-colour restorative materials in the Oral cavity. For this purpose, the quality and handling of VITA Easyshade must be verified from a clinical perspective.
57	1shruti Lakhanpal, 2menon.S Neelima		Vitro	Digital camera, Polarizer, Shade matching, Spectrophotometer.	Digital camera, Spectrophotometer.	Natural teeth	20	Extracted premolars	A statistically significant correlation was found to exist between the spectrophotometer and PDIM for all CIE $L*$, $a*$, and$b*$color coordinates.
58	If Alshiddi, Lc Richards		Vitro	Spectrophotometer.	Spectrophotometer	Natural tooth	5/M 4/F		Overall, the spectrophotometric method was more accurate but 'trained' students tended to be more accurate in Matching shade using the visual method and were significantly better in matching the value visually than Un trained students when using the.
59	Salma A. Bahannan		Vitro	Shade guide &spectrophotometer	, vita 3d master, spectrophotometer	Natural tooth			The shade matching device was significantly better than the conventional visual method. With both

							techniques, neither experience nor gender influenced shade matching quality.
60	John D. Da Silva, Scm, A Sang E.Park, Hans-Peter Weber, Dent, Cshigemi Ishikawa-Nagai,	Vivo	Spectrophotometer	Spectrophotometer	Natural tooth		n this clinical study, crowns fabricated using a dedicated spectrophotometer had a significantly better color match and a lower rate of rejection due to shade mismatch compared to crowns fabricated with a conventional Shade-matching method.
61	Gabriele Corciolani, Alessandro Vichi, Chris Louca, Marco Ferrari	Vitro	Visual and instrumental shade selection	Vita 3d master, spectrophotometer VITA Omega 900 and VITA VM 13.			Both VITA VM 13 and VITA Omega 900 ceramic systems showed a color match with the shades 2M3, 3M2, and 4M2 of the VITA 3D-Master shade guide to be within the limits for clinical acceptability
62	Cristina Gomez Polo Miguel Gomez-Polo Alicia Celemin-Vinuela Juan Antonio Martı´Nezva´ Zquez De Parga	Vitro	Visual and instrumental	3DMaster Tooth guide (Vita-Zahnfabrik Easy- Shade Compact (Vita-Zahnfabrik) spectrophotometer.	Natural teeth	1361	Maxillary central incision	This study reveals differences between the measurement of colour via spectrophotometry and the visual shade selection method.

3. Discussion

Visual Spectrophotometer According to reference taken from 21 articles with a sample size of about 4534 describes that visual Spectrophotometer photography increase the predictability of shade selection for aesthetics in dental restorations. It also states that repeatability & reliability was better in spectrophotometer than in any other methods of shade selection

Shade Guide In a total of 14 studies & 7864 samples were taken and comparative studies were conducted between visual shade guide and instrumental shade matching. Out of the above mentioned 14 studies, in 12 studies concluded a clinical study using vita 3D master, which provided us with an inference that visual shade guide is much better than the commercially available other shade guide and it is clinically acceptable. 2 other studies inferred better color replication in visual matching. In another study, visual shade selection could not achieve clinically compatible shade matching result.

Adobe Photoshop software Of reference taken from 2 articles with sample size of 128, Adobe Photoshop values indicate a clinically acceptable difference, suggesting that the independent examiners behaved similarly in obtaining the coordinated values in the automatic mode. Visual Graphic computer software: 1 study using this software with sample size12, showed better performance was achieved by graphic computer than visual shade matching.

Digital camera about 3articles with sample size was 245; the authors concluded that DSLR cameras can be used as an alternative to spectrophotometer as both values are different but it can be used as a tool for dental shade matching. It also gives better color replication.

Light condition From reference taken from 3 articles with sample size was 232 infra-red that the LED light and natural light gives good shape and color determination and aesthetics.

Colorimeter A total of 9 articles with sample size of 367 inferred that Digital colorimeter is more accurate than visual shade matching. In another comparative study between colorimeter and spectrophotometer, spectrophotometer was found to give better results.

In this systematic review evaluated 62 studies, in which 21 articles described about comparison the efficiency of visual shade method and instrumental method, 14 article described about the shade guide, 16 studies compare the visual and colorimeter, 2 studies described the digital camera, 1 of the article describes about the usage of Adobe Photoshop for accuracy in shade selection. Visual shade matching by using commercially available shade guides is one of the conventional methods of shade selection, but visually analyzing using naked eye will result in errors due to improper. Therefore the introduction of instrumental shade match device such as spectrophotometers and colorimeters eliminates errors caused by visual methods. Though colorimeters eliminate visual errors, it's not appropriate for complex color analysis such as metamerism. This disadvantage again overcome by spectrophotometers which are the most precise, accurate and sophisticated color measurement instrument available for color quality control and color formulation. A spectrophotometer has high Precision and increased Versatility. It is suitable for more complex color analyst it can determine the spectral reflectance at each wavelength. Recently, DSLR digital cameras are widely used for shade selection. Despite of providing good image information by digital colour imaging modality, it has a drawback of specular reflection caused by saliva or roughness on the tooth surface might cause artifacts in image analysis.

4. Summary

The conventional method of visual shade matching with the help of commercially available shade guides was being used for shade selection. But this method has proven to

have disadvantages as it is impossible to replicate exact shade match with the naked eye. With the advancement in technologies, now we have newer instruments for shade selected such as colorimeter, digital camera, spectrophotometer, etc. In order to elucidate the accuracy, reliability and efficiency of various instrumental methods of shade selection, many comparative studies have been conducted. Out of about 53 studies, 27 studies used instrumental methods stated that instrumental was better in accuracy and efficiency than conventional method. Four cases with high aesthetic concern instrumental methods are to use for better results. According to reference taken from 21 articles with a sample size of about 4534 descriptors that visual Spectrophotometer photography increases the predictability of shade selection for aesthetics in dental restorations. Thus, shade selection using spectrophotometer has better reliability and accuracy than the other methods.

5. Conclusion

This systematic review evaluated 62 studies that compared the accuracy of all visual and instrumental shade matching methods. According to this study visual methods and instrumental methods such as colorimeter and digital photography has lesser reliability and accuracy in shade selection of teeth. Even though the accuracy of shade selection is best using spectrophotometer, cost wise it is very high. Inconsistency of visual method is not inferior to instrumental shade matching, similarly digital camera and colorimeter used for shade matching accuracy was comparable to spectrophotometer method. Therefore patient priorities play a major role in deciding the method of shade selection for every individual case.

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