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Review Article

A SYSTEMATIC REVIEW OF EFFICACY OF SHADE MATCHING IN PROSTHODONTICS

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ABSTRACT

Aims &Objectives: This systematic review evaluated various methods of shade matching in prosthodontics.
Materials &Methods: The following databases were searched for studies comparing different shade matching methods. MEDLINE (pubmed), Embase, and Google scholar. Reference lists of articles were also searched.
Results: This systematic review evaluated 36 studies that comparing the efficacy of different tooth shade-matching protocols, 21 of which compared visual and instrumental shade measurements, 9 studies utilizes only instrumental measurements out of which 4 compared colorimetric and spectrophotometric measurements. Remaining 6 studies utilizes visual measurements includes day light or commercial light.
Conclusion: Shade matching using a spectrophotometer is the most precise and accurate. Although visual shade matching is inconsistent, this method is not necessarily inferior to colorimetric measurements in terms of precision.

INTRODUCTION

Color is a property of light. Objects have no color of their own; they just reflect a particular wavelength from the color spectrum. For example a blue object absorbsall of the wavelengths, except for blue. The remaining wavelengths enter our eyes and this is what we see[1]. The most popular method for describing color is the Munsell system. The three attributes of color in this system are called *Hue, Chroma and* Value[1.]

Limitations in materials and techniques may make a perfect shade selection impossible. Shade selection should be approached in a methodical and organized manner[1]. Successful shade matching remains one of the most important elements of esthetic success and patient satisfaction[2]. The success of shade matching is determined on the basis of functional and esthetic results[3]. To achieve esthetics, four basic determinants are required in sequence; viz., position, contour, texture and color. Because it imposes several demands on the artistic abilities of the dentist and the technician, knowledge of the underlying scientific principles of color is essential[4]. Significant advances in dental porcelains, resins, bonding chemistry, and cements have accompanied developments in color measurement optics to create a marketplace that is exciting at times overwhelming[5].Technology-based systems provide with advantage of natural looking restorations. They include RBG devices, colorimetersand spectrophotometers[3]. The clinical focus of color matching in prosthodontics is the beginning and the end, that is, shade selection and evaluation of the final result[5].

MATERIALS AND METHODS

This topic is reviewed systematically as shown in the flow chart for systematic review

DISCUSSION

This systematic review evaluated 36 studies that comparing the efficacy of different tooth shade-matching protocols, 21 of which compared visual and instrumental shade measurements, 9 studies utilizes only instrumental measurements out of which 4 compared colorimetric and spectrophotometric measurements. Remaining 6 studies utilizes visual measurements includes day light or commercial light.

The samples used in the studies ranged from natural and extracted teeth to shade tabs. These differences likely caused variations in the results. Seventeen of 36 studies focused on the middle third of the tooth, which may not represent the full color gradation of the natural tooth surface. Few studies assessed the whole tooth surface. In some studies, evaluation of the overall color or each third of a tooth (ie, the incisal, middle, and cervical thirds) produced slightly more consistent shade

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matching, but no statistically significant conclusions could be drawn from such assessments.

Of the studies presenting data on precision, 11 reported more precise outcomes using a spectrophotometer, regardless of the sample type, area assessed, or shade matching environment. Assessment of colorimeters with respect to precision and accuracy varied greatly among the studies. In contrast, Yilmaz and Karagaclioglu indicated that even a visual measuring method was more precise than colorimeters. Some studies involving comparison of digital imaging assessment with conventional visual measurements. They reported higher accuracy with the digital imaging method. Schropp found no statistical differences between visual and digital measurements.

Table 1 Search strategy

Study parameters	Search No.	Search terms	Results
Pubmed & Embase & Google Scholar	1.	**(shade matching) OR shade selection**	497
	2.	**((shade evaluating) OR shade assessing) OR shade measuring**	217
	3.	**((teeth) OR tooth) OR dental**	521281
	4.	1 AND 3	354
	5.	2 AND 3	93
	6.	4 OR 5	425

Table 2 Inclusion and Exclusion criteria

Study parameter	Inclusion criteria	Exclusion criteria
Study design	1. Systematic Review articles. 2. Meta analysis. 3. Randomized control studies. 4. Cohort studies. 5. Case Control studies.	1. Case reports. 2. Case series. 3. Letter to Editor. 4. Book reviews. 5. Professional communications. 6. Systemic reviews. 7. Animal studies.
Publication date	From last 10 years to August 30, 2015	Unpublished or ongoing trials, published before 10 years
Language	English	Non-English
Conflict of interest	Free of conflicts of interest	Comparing specific brands of instruments

Table 3 Selection process

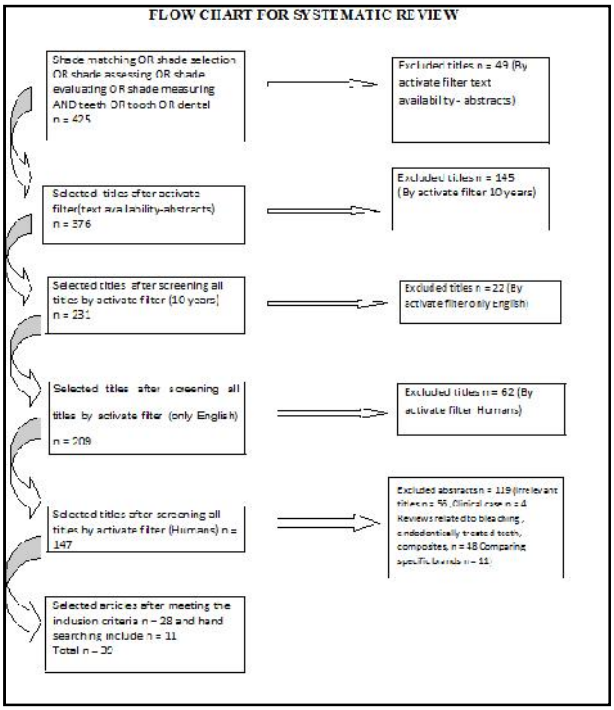
Assessment	Exclusion criteria
Titles	Irrelevant topics (eg, caries, non-vital, fracture)
Abstracts	Irrelevant study design (case series, case reports, animal studies)
Full text	No applicable data or unretrievable

The use of a spectrophotometer that evaluates the color of the entire tooth surface should be recommended when highly esthetic restorations are required. A colorimeter may be useful in shade matching, but it is recommended to combine colorimetric measurements with visual measurement. The use of digital imaging for shade analysis can improve communication between clinicians and technicians. The authors recommended digital imaging as an auxiliary method to visual measurement when a spectrophotometer or colorimeter is not available. Visual shade matching is subjective and inconsistent. However, when exact color replication is unnecessary, visual assessment should be used because of its convenience and low cost.

Summary

Visual color determination by comparing the teeth to a shade guide has been the most often used method in dentistry. Some authors concluded that human eye is efficient in detecting even small differences, while other authors have commented that the human evaluation of tooth shade is unreliable[32].

Visual tooth shade selection is characterized by high intra-examiner variability, due to the numerous subjective factors that affect color selection. Electronic shade selection devices have the potential for more accurate and reliable selection of a tooth color, since they are not influenced by the significant parameters in visual selection, such as illumination and operator variability[33].Media emphasis on an “esthetic standard” is probably responsible for driving the most recent advances in dental imaging and shade matching. Although we tend to focus on color matching, it is an appearance match that we are after, so the optical properties of translucency, light scattering, surface texture, and gloss and the basic principles of esthetics, including tooth size and proportion, symmetry, outline form, and overall harmony and just as important, if not more so, to a successful restorative match[5].



Spectrophotometric shade analysis seems to be more reproducible than the visual shade determination[34]. The ability of dental students to match shades was significantly better with a correcting light source than under natural light[35].With more research and development it should be possible to achieve a higher percentage of successful matches than the approximately 50 ^{0} /$_{0}$ experiences today, but even with the acceleration of progress in color matching technology, the success of a restorative effort remains dependent on adequate tooth preparation, tissue management, and treatment planning[5]. The color of the all-ceramic specimens with different veneering porcelain shades is influenced by repeated firings and it should be considered during shade selection and fabrication[36].

Assessment of the Articles

Study	Setting	Method	Device	Sample			Assessment
				TYPE	NO.	AREA	
Francis M.Curd *et al*[35] 2006	Invitro	Visual -natural light -commercial light	Vita A Vita B Vita C	Natural light Commer-cial light	216	Labial	Light correcting device is better than natural light
Ji-Hoon Park *et al*[14] 2006	Invitro	Visual -shade tabs	Vita lumin Chromoscop	Shade tabs	2	Middle 3rd	Influence of illuminants on shade matching should be considered
E.Klemetti *et al*[6] 2006	Invivo	Visual Colorimeter	Vita lumin Vita 3D Procera ShadeEye	Natural teeth	4	Middle 3rd	Digital colorimeter may be in advantage over traditional method
Alvin G.Wee *et al*[21] 2006	Invitro	Digital camera	Nikon D100 Canon D60 Sigma SD9	Shade tab	65	Middle 3rd	Commercial SLR digital camera should combined with appropriate calibration & can use in color replication
R.Khurana *et al*[23] 2007	Invivo	Spectrophotometer Colorimeter	Easyshade Shade vision Spectroshade	Natural teeth	6	Labial	Spectroshade micro machine provided the most repeatable measurements
Foteini V. Derdilopoulou *et al*[34] 2007	Invivo	Visual Spectrophotometer	Chromascop Spectroshade	Natural teeth	3,758	Labial	Spectrophotometric shade analysis seems to be more reproducible
Alma Dozic *et al*[24] 2007	Invivo Invitro	Spectrophotometer Colorimeter	Easyshade Shadescan Ikam Shadeeye IdentacolorII	Extracted Natural teeth	25	Middle 3rd	Easyshade&Ikam systems were most reliable
Q.Li *et al*[10] 2007	Invivo	Visual Spectroradiometer	Vintage halo ShadeeyeNCC	Natural teeth	20	Middle 3rd	ShadeEye NCC chroma meter make better results
RadeD.Paravina *et al*[15] 2007	Invivo	Visual spectrophotometer	Easyshade Vita classical	Natural teeth	1064	Middle 3rd	Clustering & Optimization enabled better representation than existing dental shade guide
Stephen J.Chu *et al*[9] 2007	Invitro	Visual Instrumental	Digital camera Spectrophotometer	Shade tab	-	Incisal 3rd Middle3rdG ingival3rd	Successful shade taking involves technology based systems, shade tabs, & reference photography
John D.Da Silva *et al*[28] 2008	Invivo	Visual Spectrophotometer	Vita C Vita 3D Chromascop Crystaleye	Natural teeth	36	All 3rds of labial surface	Spectrophotometer had a significantly better color match
Lars Schoropp[25] 2008	Model	Visual DI	Vita 3D Canon EOS	Shade tabs	12	Labial Surface	Digital photographs & computer software was more reliable
GozdeCelik *et al*[36] 2008	Invitro	Spectrophotometer	Easyshade	Vita Shade tab ivocular	10 10	Middle 3rd	Color of porcelain shades influenced by repeated firings
SeungyeeKim-Pusateri *et al*[26] 2009	Invitro	Instrumental	Shade vision Spectroshade Easyshade Shadescan	model	3	Middle3rd	Vita Easyshadehad both reliability & accuracy
Andrej M.Kielbassa *et al*[22] 2009	Invitro	Visual Spectrophotometer	Chromascop Spectroshade	Extracted natural teeth	288	Middle3rd	Spectrophotometric assessment was more reproducible & objective

It can be concluded that the perception of color difference seems to be learned trait. When compared to a lay person, dental surgeons are more acute in perceiving color changes and do not accept the color difference between teeth to a higher degree[37].

Besides visual assessment with a shade guide, tooth color can be measured with colorimetry, spectrophotometry, and digital cameras[24]. The theoretical benefits of using the spectrophotometer are that the measurements are not subject to human biases, subjectiveness, vision deficiencies, or an unsteady light source. It also allows easier communication between individuals[16]. However, the final color matching may be affected by the combination of ceramic color and thickness, together with the luting agent and the color of the underlying dental structure[16]. Shade matching devices could help the clinician and technician achieve a better shade choice.

The combination of visual shade analysis and digital shade measurement together lies in the precise predictability of the miscibility of shades[38].

Commercially available electronic systems fortooth color measurements show different levels ofaccuracy and precision[24]. Digital imaging has great potential for color measurement in terms of accuracy[2].There was significant difference of ΔE between natural teeth and crowns constructed from different materials and 0.8, 1.2, and 1.5 mm ceramic thicknesses or combinations of both.[16]. At the highest 1.5 mm crown thickness, there was no significant difference between natural teeth and crowns constructed from different ceramic material[16]. The optical behavior of ceramic materials differs from system to system.

Assessment of the articles

PanagiotisE.Lagouvardos *et al*[33] 2009	**Invitro**	**Colorimeter Spectrophotometer**	**ShadeEye NCC Easyshade**	**Extracted natural teeth**	**31**	**Middle3rd**	**Lightness & shade guide systems affect interdevice reliability**
WD Browning *et al*[32] 2009	Invivo	Visual Spectrophotometer	Vita 3D Easyshade	Natural teeth	95	Middle3rd	Easyshade were more frequently an exact color match
Gabriele Corciolani *et al*[12] 2009	Invitro	Visual Spectrophotometer	Vita classical Vita 3D Easyshade	Shade tabs	15	Labial surface	Vita 3D-master tooth guide was found to be more reliable than vita classical guide
Ahmad Judeh *et al*[38] 2009	Model Invivo	Visual Spectrophotometer	Vita C Easyshade	Shadetab Natural teeth	9 9	Middle3rd	Spectrophotometer was more likely to match the shade than the visual method
Q.Li *et al*[17] 2009	Invivo	Visual Colorimeter	Vita lumin Vita 3D Shofu NCC Chroma	Natural teeth	60	Middle 3rd	Visual shade matching could not achieve a clinically compatible shade matching result
N.Corcodel *et al*[7] 2009	Invivo	Visual	Natural daylight Daylight lamp	Shade tabs	26	Labial surface	Daylight lamp helps to standardize light conditions
BurakYilmas *et al*[20] 2010	Invitro model	Visual Colorimeter	Vitapan classical ShadeEye NCC	Ceramic specimen	25	Middle 3rd	Visual shade determination yielded better color replication
Aki yoshida *et al*[30] 2010	Invitro	Spectrophotometer	Crystaleye	Natural teeth	1	Incisal3rd Middle3rd Cervical3rd	Spectrophotometer accurately communicate important information about shade of tooth
N.Coecodel *et al*[11] 2010	Invivo	Visual	Visual	Linear vita3D Original vita 3D Shade tab	30	Labial surface	Regarding performance & time needed in shade matching was not different with Linear or 3D guide
Vimal K.Sikri[4] 2010	Invitro	Visual Instrumental	Visual Instrumental	-	-	-	Concept of color is essential for achieving good esthetics
Karl Martin Lehmann *et al*[29] 2011	Invivo	Spectrophotometer Colorimeter	Easyshade Shade pilot Shade vision	Natural teeth	15	Cervical Body Incisal	Clinically acceptable intra-device repeatability for all tooth regions when using same color measuring device
Mohammed Shammas *et al*[1] 2011	Invitro	Visual Instrumental	Visual Instrumental	-	-	-	Understanding the science of color & color perception is important
VinayaBhat *et al*[3] 2011	Invitro	Visual Instrumental	Visual Instrumental	-	-	-	Successful shade taking involves combination of technology, shade tabs & reference photographs
Hui Chen *et al*[2] 2012	Invitro	Visual Spectrophotometer Colorimeter	Visual Spectrophotometer Colorimeter	articles	26	-	Spectrophotometer was the most precise & accurate method for shade matching
K Yuan *et al*[18] 2012	Invivo Invitro	Visual Instrumental	Shade pilot Easyshade ShadeEyeNCC	Shade tabs Natural teeth	80 85	Middle 3rd	Combination of instrumental & visual shade matching is recommended
Shobha Rodrigues *et al*[8] 2012	Invivo	Visual	Vita lumin Chromascop Vita 3D	Natural teeth	800	Labial surface	Vita 3D master had the greatest variety of shades
P.B.Ozat *et al*[39] 2013	Invivo	Visual	Vita 3D Easyshade	Natural teeth	54	Labial surface	Dentists can match clinically acceptable shades in visual method
P.Magne *et al*[13] 2013	Invitro	Visual Spectrophotometer	Vita Miris2 Easyshade	Shade tab	2	Labial surface	Prefabricated anatomic dual-laminate shade guide is as efficient as custom shade guide
Motaz Ahmed Ghulman *et al*[16] 2013	Invitro	Spectrophotometer	Easyshade	Extracted natural teeth	90	Middle 3rd	Increasing the thickness of fabricated crowns enhances color match
Jian Wang *et al*[27] 2014	Invitro	Visual Instrumental	Vita 3D Crystaleye	Shade tabs	29	Labial surface	Computer color matching system is accurate and effective for reproducing tooth shades
TeutaPustina-Krasniqi *et al*[19] 2015	Invivo	Visual Spectrophotometer	3D mastershade Easyshade	Natural teeth	82	Middle3rd	Combination of visual & digital shade measurement should be used

Knowledge of the optical properties of different thicknesses of available ceramic systems enables the clinician to make appropriate choices when faced with various esthetic challenges[16]. Consistency and reliability of visual shade matching are questioned, and instrumental shade-matching methods such as using a spectrophotometer are claimed to provide the most precise and accurateshade-matching outcomes,

where a review of the related literature suggests that visual shade matching as the conventional technique to determine tooth shade should be used in combination with instrumental methods whenever possible, as they complement each other and can lead towards predictable aesthetic outcome .It can be concluded that visual shade matching is still an inevitable method and when reliability and repeatability of commercially available shade tabs or shade-matching instruments are

considered, such features of human eye should also be judged[39].

CONCLUSION

This systematic review evaluated the efficacy of different tooth shade-matching methods. Shade matching using a spectrophotometer is the most precise and accurate. Although visual shade matching is inconsistent, this method is not necessarily inferior to colorimetric measurements in terms of precision. Digital imaging has great potential for color measurements in terms of accuracy. In addition, controlled standards are required to regulate shade-matching procedures and comparison of different shade-matching outcomes. Thus successful shade matching involves technology based systems, shade tabs, and reference photography.

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