A Clinical Evaluation of Inter Observer Variability in Shade Selection by Using Conventional and Spectrophotometric Shade Matching Devices

Dr. Deepak Mahla, [1] Dr. Siddharth Mangal, [2] Dr. Abhishek Bhartiya, [3] Dr. Neeraj Yadav, [4] Dr. Pradeep Kumar, [5] Dr. Rajendra Singh [6]

1. **Dr. Deepak Mahla**
   Reader, Department of Prosthodontics Crown & bridge, Rajasthan Dental College and Hospital, Jaipur, Rajasthan, India
2. **Dr. Siddharth Mangal**
   Reader, Department of Oral and Maxillofacial Surgery, Rajasthan Dental College and Hospital, Jaipur, Rajasthan, India
3. **Dr. Abhishek Bhartiya**
   Senior Lecturer, Department of Prosthodontics Crown & bridge, Rajasthan Dental College and Hospital, Jaipur, Rajasthan, India
4. **Dr. Neeraj Yadav**
   Senior Lecturer, Department of Prosthodontics Crown & bridge, Rajasthan Dental College and Hospital, Jaipur, Rajasthan, India
5. **Dr. Pradeep Kumar**
   Professor & Head, Department of Periodontology, Rajasthan Dental College and Hospital, Jaipur, Rajasthan, India
6. **Dr. Rajendra Singh**
   Reader, Department of Oral and Maxillofacial Surgery, Jaipur Dental College and Hospital, Jaipur, Rajasthan, India

Abstract

Determining an accurate shade match is one of the most critical steps for cosmetic procedures. Shade selection for dental restorations is usually done visually by matching with a shade guide. Different persons may make different interpretations of the light stimulus, and thus shade selection could become a subjective assessment. Aim of this study was to assess the reliability of shade matching of dentists using conventional shade matching systems and to analyse if knowledge and experience of dentists affect the shade selection of natural teeth for restorative rehabilitation.

Settings and Design: A total of 30 undergraduate dental students studying in M. G. Dental College were selected as subjects for the study after fulfilling exclusion and inclusion criteria. Ten investigators comprising dental surgeons with different levels of training and experience were included in this study.

Methods and Material: The shade selection of right maxillary central incisor of each subject was done by all nine investigators (Group 1,2 & 3) using both Vita classical and Vitapan 3D Master tooth shade guides and the values were recorded. Consequently, the principal investigator (Group 4) recorded shade of each subject using Digital Spectrophotometer and the readings were noted down. Finally, all the data recorded were converted to mathematical coordinates according to CIE-L*a*b values.

Statistical analysis used: All statistical analysis were performed using IBM SPSS 19.0 Software.

Result: Results showed that there was no significant difference amongst different groups but there was significant difference when the group 1, group 2 and group 3 were compared with group 4.

Conclusions: This study showed that among the groups of investigators, dental interns showed a slight edge over postgraduate students and senior faculty.

Keywords: Shade Selection, Inter-obsever, Spectrophotometer, CIE L*a*b*.

INTRODUCTION

One of the main driving forces in dentistry today is the need to provide restorations that match the colour of the existing dentition. However, selecting the correct shade and fabricating a restoration to match this colour is subjective and therefore varies between individuals. Included within restorative and esthetic dentistry is color science, in the practice of shade matching. Today's color science principles still originate with Newton in the 1600s and are still based on Munsell's basic three-dimensional notation theory of the early 1900s.[1]

While color instrumentation and shade matching procedures have been widely addressed in dental literature, the most popularly used shade guides have not changed much through the last 50 years. The Vita Toothguide 3D-Master was developed with a systematic arrangement for a wide range of natural dentition shades.[2]

Spectrophotometers are amongst the most accurate, useful and flexible instruments for overall color matching and color matching in dentistry. A spectrophotometer contains a source of optical radiation, a means of dispersing light, an optical system for measuring, a detector and a means of converting light obtained to a signal that can be analysed. Some of the commercially available spectrophotometers are Crystaleye (Olympus, Tokyo, Japan), Vita Easyshade Compact (Vita Zahnfabrik, Bad Sa¨ckingen,Germany), Shade-X (X-Rite, Grandville, MI), SpectroShade Micro (MHT Optic Research, Niederhasli, Switzerland) etc.[3,4,5]

All colour matching instruments use L*a*b color system. The CIE (Commission Internationale d'Eclairage) was authorized to develop a mathematically defined standard color table which should fulfil the wish for precision and objectiveness. Starting from this basic concept, CIE developed the color chart (Standard Color Table, Standard Valency System). Maxwell's traditional, trichromatic values RGB were converted into the three new tristimulus values x, y and z. In the resulting color chart, the value x represents the horizontal axis and the value y the vertical axis.[6]

Recently, digital systems (spectrophotometers, colorimeters or digital cameras) have been used to measure tooth color. Within these systems, color is expressed in CIEL*a*b* space, which provides its specification in three dimensions and allows for more accurate assessments. These digital systems are precise instruments that produce highly reliable, easily evaluated results in terms of visual importance.[7,8] However, till recently, high cost and complex operation have restricted their use to laboratory or clinical research.[8,9]

Visual color determination by comparison of tooth color with a standard (eg, commercially available shade guides) is the most frequently applied method of color assessment in dentistry.[10,11] This procedure is regarded as difficult to reproduce and highly subjective; variables that affect shade selection include external light conditions, metamerism, age, sex, fatigue of the eye, experience, and probably color blindness.[7,11,12] Instrumental methods for determination of tooth color are objective and more rapid than visual shade matching. Computer-assisted spectrophotometers and colorimeters generate mathematically comparable L*a*b* (lightness, red/green, yellow/blue) or L*C*h* (Value, Chroma, Hue) values that quantify color.[7,10]

Shade selection through the use of shade guides is inadequate due to lack of standardization. Both intra and inter-operator errors are common in shade selection.[11] Several methods for shade selection have been investigated to find a justifiable one.[1,13]

A phenomenon called metamerism occurs when two colors appear to match under a given lighting condition but have a different spectral reflectance. As a result, in different lighting condition, the colors do not match. Currently, there are several electronic shade-matching instruments available for clinical use. A spectrophotometer functions by measuring the

spectral reflectance or transmittance curve of a specimen. A prism disperses white light from a tungsten-filament bulb in the spectrophotometer into a spectrum of wavelength bands between 5 and 20 nm. The amount of light reflected from a specimen is measured for each wavelength in the visible spectrum. Spectrophotometers have a longer working life than colorimeters and are unaffected by object metamerism.[14]

In addition to the factors previously mentioned, the level of knowledge and training of the operators may also affect the accuracy of shade matching process using conventional shade guides. Studies have shown that there are varied results in shade matching ability among individuals. Recent studies have shown the high level of accuracy of shade matching by currently available spectrophotometers. However, there are very few studies regarding the effect of the knowledge and level of training of operator on the shade matching results as compared to spectrophotometers.

Hence, this study was planned to compare inter-observer variability in shade matching ability of dentists of different training level and experience by using conventional shade guides and a digital spectrophotometer. The null hypothesis was that there will be no significant difference in shade matching among different observers using conventional shade guides and also when compared with digital spectrophotometer.

Aim of this study was to assess the reliability of shade matching of dentists using conventional shade matching systems and to analyse if knowledge and experience of dentists affect the shade selection of natural teeth for restorative/prosthodontic rehabilitation.

Objectives of this study was to compare the results of shade matching of each group of investigator using conventional methods to results obtained using the commercially available digital spectrophotometer and to compare the inter-observer variability in shade selection.

SUBJECTS AND METHODS

A total of 30 undergraduate dental students were selected as subjects for the study. Prior to this, 108 undergraduate students were screened using the inclusion and exclusion criteria of which 82 students were eligible to be included in the study. Out of these 82 students, 30 were selected randomly using table of random numbers (Simple Random Sampling).

The inclusion and exclusion criteria were applied.After obtaining their consent to be a part of the research study, a detailed clinical exam was performed and a thorough oral prophylaxis was done.

Investigators comprising dental surgeons with different levels of training and experience were included in this study, viz. senior faculty members (12-27 years of experience), post graduate students (6-7 years of experience) and dental interns (2-3 years of experience). Each investigator was ruled out for colour blindness using Ishihara plates (Tokyo, Kanehara and Co.) before inclusion in the study.

METHOD OF COLLECTION OF DATA METHODOLOGY

Thirty undergraduate dental students were randomly selected for the study after fulfilling exclusion and inclusion criteria. Students selected underwent oral prophylaxis before participating in the study.

The investigators were grouped as Group 1 (Senior Faculty members), Group 2 (Postgraduate Students), Group 3 (Dental Interns) & Group 4(Postgraduate Student).

All investigators were given a questionnaire to fill out their name, age, gender and years of experience. Years of experience was counted as number of years from the third professional year of BDS course to the current time.

Before commencement of the study, all the investigators were given brief training about the shade selection technique with both conventional shade guides and introduction to tooth colour differentiation based on value, Chroma and Hue. Following this, the shade selection of right maxillary central incisor of each undergraduate dental student was done by all nine investigators (Group 1, Group 2, Group 3) using both Vita classical and Vitapan 3D Master tooth shade guides and the values were recorded using a structured Proforma. Consequently, the principal investigator (Group 4) recorded shade of each subject using Digital Spectrophotometer and the readings were noted down.

VISUAL SHADE MATCHING PROCEDURE

Each investigator selected the shade of the maxillary right central incisor of all the subjects visually separately using both conventional shade guides. This was done between 1100 hrs and 1400 hrs in daylight on a clear day. Examinations were held in a separate room, not to be influenced by the other investigators. The conditions of tooth shade match were: natural light, a sunny day at noon time, in front of the window.

Before shade taking, the teeth were cleaned with a mixture of water and pumice and a brush on a low speed handpiece to remove any accumulated plaque and stain. Lipstick if any, was removed and the subjects were covered with a gray bib before the shade selection.

During the visual shade selection using the shade guides, the participants were upright, and the shade guides were positioned at the eye level of the examiner and at the level of the maxillary central incisor of the participant. The selected shade was individually recorded for each participant.

The investigators were informed not to focus at the teeth for a longer period of time to avoid fatigue to the eyes. They were given sixty seconds for shade selection and after every ten seconds of gazing they were asked to rest the eye by looking into a neutral blue card.

DIGITAL SHADE MATCHING

The principal investigator determined the shade of maxillary right central incisor of each subject by using the digital spectrophotometer as per the manufacturer's instructions. In this case the light or environment conditions did not influence the results. The readings corresponding to both Vita Classic and Vita 3D Master Guides were recorded.

The colour of the Vitapan classical and Vita Classical shade guide tabs was measured and CIE L*a*b* values were noted down by digital Vita Easyshade device. This procedure was performed by switching the device mode to 'Shade Tab' mode and the measurement were perform similar to the tooth measurement procedure describe earlier.

STATISTICAL PROCEDURE

Mean and Standard Deviation of each variables was calculated for all the groups and one-way ANOVA test was used for comparision of group mean. For sake of multiple comparison post hoc test was applied. All statistical analysis were performed using IBM SPSS 19.0 Software.

RESULTS

Dependent Variable	(I) Group Name	n	Mean	SD	(J) Group Name	Mean Difference (I-J)	Std. Error	'p'
3D Master_L*	Group 1	30	75.51	2.44	Group 2	0.58	0.73	0.4309
					Group 3	-0.17	0.73	0.8168
					Group 4	-7.29	0.73	0.0000
	Group 2	30	74.93	2.69	Group 1	-0.58	0.73	0.4309
					Group 3	-0.75	0.73	0.3086
					Group 4	-7.87	0.73	0.0000
	Group 3	30	75.68	2.46	Group 1	0.17	0.73	0.8168
					Group 2	0.75	0.73	0.3086
					Group 4	-7.12	0.73	0.0000
	Group 4	30	82.80	3.61	Group 1	7.29	0.73	0.0000
					Group 2	7.87	0.73	0.0000
					Group 3	7.12	0.73	0.0000

*** p < 0.05 : significant difference**

Inference - The data in Table No 2 indicate that Intergroup variability is not significant amongst group 1, 2 and 3. For L*(value), least difference can be seen among group 1 and group 3. Highly significant difference can be seen when group 1, 2 and 3 are compared individually with group 4. However, the least mean difference can be found in group 3 when group 1, 2 and 3 are compared with group 4.

Dependent Variable	(I) Group Name	n	Mean	SD	(J) Group Name	Mean Difference (I-J)	Std. Error	'p'
3D Master_a*	Group 1	30	0.36	0.57	Group 2	-0.26	0.21	0.2176
					Group 3	-0.10	0.21	0.6505
					Group 4	1.28	0.21	0.0000
	Group 2	30	0.62	0.76	Group 1	0.26	0.21	0.2176
					Group 3	0.17	0.21	0.4338
					Group 4	1.54	0.21	0.0000
	Group 3	30	0.45	0.65	Group 1	0.10	0.21	0.6505
					Group 2	-0.17	0.21	0.4338
					Group 4	1.38	0.21	0.0000
	Group 4	3+0	-0.93	1.17	Group 1	-1.28	0.21	0.0000
					Group 2	-1.54	0.21	0.0000
					Group 3	-1.38	0.21	0.0000

*** p < 0.05 : significant difference**

Inference - The data in Table No. 1 indicate that Intergroup variability is not significant amongst group 1, 2 and group 3. For a*(Red/Green axis), least difference can be seen among group 1 and 3. Highly significant difference can be seen when group 1, 2 and 3 are compared individually with group 4. However, the least mean difference can be found in group 1 when group 1, 2 and 3 are compared with group 4.

Dependent Variable	(I) Group Name	n	Mean	SD	(J) Group Name	Mean Difference (I-J)	Std. Error	'p'
3D Master_b*	Group 1	30	15.39	3.14	Group 2	0.89	0.84	0.2916
					Group 3	0.45	0.84	0.5980
					Group 4	-1.70	0.84	0.0463
	Group 2	30	14.50	2.79	Group 1	-0.89	0.84	0.2916
					Group 3	-0.45	0.84	0.5967
					Group 4	-2.59	0.84	0.0026
	Group 3	30	14.95	2.67	Group 1	-0.45	0.84	0.5980
					Group 2	0.45	0.84	0.5967
					Group 4	-2.14	0.84	0.0123
	Group 4	30	17.05	4.22	Group 1	1.70	0.84	0.0463
					Group 2	2.59	0.84	0.0026
					Group 3	2.14	0.84	0.0123

*** p < 0.05 : significant difference**

Inference - The data in Table No. 4 indicate that Inter group variability is not significant amongst group 1, 2 and 3. For b*(Yellow/Blue axis), least difference can be seen among group 1 and 3. Significant difference can be seen when group 1, 2 and 3 are compared individually with group 4. However, the least mean difference can be found in group 1 when group 1, group 2 and group 3 are compared with group 4.

Dependent Variable	(I) Group Name	n	Mean	SD	(J) Group Name	Mean Difference (I-J)	Std. Error	'p'
Classical L*	**Group 1**	30	75.02	1.89	Group 2	-0.15	0.66	0.8252
					Group 3	-0.21	0.66	0.7472
					Group 4	-7.78	0.66	0.0000
	Group 2	30	75.16	2.36	Group 1	0.15	0.66	0.8252
					Group 3	-0.07	0.66	0.9191
					Group 4	-7.64	0.66	0.0000
	Group 3	30	75.23	1.94	Group 1	0.21	0.66	0.7472
					Group 2	0.07	0.66	0.9191
					Group 4	-7.57	0.66	0.0000
	Group 4	30	82.80	3.61	Group 1	7.78	0.66	0.0000
					Group 2	7.64	0.66	0.0000
					Group 3	7.57	0.66	0.0000

*** p < 0.05 : significant difference**

Inference - The data in Table No. 5 indicate that Intergroup variability is not significant amongst group 1, 2 and 3. For L*(value), least difference can be seen among group 2 and group 3. Highly significant difference can be seen when group 1, 2 and 3 are compared individually with group 4. However, the least mean difference can be found in group 3 when group 1, 2 and 3 are compared with group 4.

Dependent Variable	(I) Group Name	n	Mean	SD	(J) Group Name	Mean Difference (I-J)	Std. Error	'p'
Classical_a*	**Group 1**	30	-0.89	0.56	Group 2	-0.09	0.20	0.6647
					Group 3	0.17	0.20	0.4069
					Group 4	0.04	0.20	0.8555
	Group 2	30	-0.80	0.72	Group 1	0.09	0.20	0.6647
					Group 3	0.26	0.20	0.2077
					Group 4	0.13	0.20	0.5384
	Group 3	30	-1.06	0.53	Group 1	-0.17	0.20	0.4069
					Group 2	-0.26	0.20	0.2077
					Group 4	-0.13	0.20	0.5171
	Group 4	30	-0.93	1.17	Group 1	-0.04	0.20	0.8555
					Group 2	-0.13	0.20	0.5384
					Group 3	0.13	0.20	0.5171

*** p < 0.05 : significant difference**

Inference - The data in Table No. 6 indicate that Intergroup variability is not significant amongst group 1, 2 and 3. For a*(Red/Green axis), least difference can be seen among group 1 and group 2 .No significant difference can be seen when group 1, 2 and 3 are compared individually with group 4. However, the least mean difference can be found in group 1 when group 1, 2 and 3 are compared with group 4.

Dependent Variable	(I) Group Name	n	Mean	SD	(J) Group Name	Mean Difference (I-J)	Std. Error	'p'
Classical_b*	**Group 1**	30	15.16	2.31	Group 2	0.70	0.72	0.3308
					Group 3	1.19	0.72	0.1019
					Group 4	-1.9286667*	0.72	0.0086
	Group 2	30	14.45	2.22	Group 1	-0.70	0.72	0.3308
					Group 3	0.48	0.72	0.5027
					Group 4	-2.6328889*	0.72	0.0004
	Group 3	30	13.97	1.77	Group 1	-1.19	0.72	0.1019
					Group 2	-0.48	0.72	0.5027
					Group 4	-3.1176667*	0.72	0.0000
	Group 4	30	17.09	4.22	Group 1	1.9286667*	0.72	0.0086
					Group 2	2.6328889*	0.72	0.0004
					Group 3	3.1176667*	0.72	0.0000

*** p < 0.05 : significant difference**

Inference - The data in Table No. 7 indicate that Intergroup variability is not significant amongst group 1, 2 and 3. For b*(Yellow/Blue axis), least difference can be seen among group 2 and 3. Highly significant difference can be seen when group 1, 2 and 3 are compared individually with group 4. However, the least mean difference can be found in group 1 when group 1, 2 and 3 are compared with group 4.

DISCUSSION

This in-vivo comparative study was conducted to evaluate whether knowledge and experience of dentists affects the shade selection of natural teeth for restorative/prosthodontic rehabilitation. The results of this study supported a part of the null hypothesis that there will be no significant difference in shade selection between different groups of investigators. But, the other part of the null hypothesis that there will not be difference between the groups and results of the digital spectrophotometer was rejected.

In this study, visual shade matching was done by investigators individually following a standard protocol under controlled viewing conditions. Efforts were made to standardize the conditions for optimal shade matching to minimize the variables that could affect the results. Digital shade matching was performed by the principal investigator of same subjects following manufacturer's instructions.

Vita Easy Shade Advance 4.0 is a latest version of digital spectrophotometer commercially by VITA. Several studies in the past have investigated the previous versions of this instrument and have found that it is reliable shade matching device in terms of both repeatability and accuracy. Alma Dozic et al, Da Silva et al and Kim-Pusateri et al have investigated various commercially available digital shade matching devices and concluded that the Vita Easy Shade device was one of the most reliable among them.[14,15,16] So, in this study we have chosen this instrument as the control to which the results of visual shade matching was compared.

The subjects chosen for the study were dental undergraduate students in the age group of 18-25 years. It was expected that subjects in this age group were likely to satisfy the exclusion and inclusion criteria. Middle third of the labial surface of maxillary right central incisor was used for shade matching. It has been stated by some authors that errors may occur in absolute colour measurements due to the curved surfaces of both the subject's maxillary central incisor and Vita shade tabs.[17,18]

Investigators were chosen among the dental interns, post-graduate students in Prosthodontics and senior faculty in Department of Prosthodontics. This was done to achieve on of the main objectives of the study to evaluate the role of training and experience of dentists on the shade matching. Culpepper has shown that there was a varied result in shade matching ability among individuals.[19] O'Brien & Nilsson also have stated that dental personnel were more discriminating in colour matching than non-dental personnel. Barrett, Anusavice & Moorehead also found that experience does play a role in the shade matching ability of dentists.[17]

Results of this study showed that there is no significant difference amongst different groups except when they were compared with group 4, i.e. the three groups with different levels of training and experience did not show significant difference in visual shade matching amongst each other.

Senior faculty' did not seem to have any additional advantage in colour matching despite additional training that the senior faculty had undergone in addition to presumably more experience in shade selection. This concurred with the study by Davison & Myslinki, that showed no significant improvement in shade selection between the Prosthodontist group and that of the dental students and general practitioners.[13] A similar finding was reported by a study by Amit V Naik et al.[20]

A noteworthy finding from the present study is that, even though there were no significant difference between groups, dental interns exhibited a slight edge over postgraduate students and senior faculty in shade matching ability when compared to a digital spectrophotometer. Similar results have been reported by Abdullah Al Farraj Al-Dosari and by Fernandes A et al.[18,21]

This finding could be attributed to their patience in utilizing all the time allowed for colour selection, concentration at work, enthusiasm and sincerity in young professionals as in any field. Besides, this variation could also be attributed to their age and hence the ability for accurate colour perception as substantiated previously by many researchers. Aging is also associated with yellowing of cornea that effects the blue and purple colour discrimination and chronic diseases, certain medications and environmental exposure to cigarette smoke, sun and lasers affect the colour perception.[18] These could also be the factors for the dental interns, being the youngest group in this study for demonstrating the highest ability for accurate shade matching.

Another important finding from the result of the present study is that though there was no statistically significant difference between groups of investigators, a highly significant difference was found between individual groups and the results obtained by the digital spectrophotometer.

Previous studies have shown varied results when visual methods of shade matching are compared with digital spectrophotometers. Ahmad Judeh et al examined the reliability of a spectrophotometer in shade selection compared to visual method. They showed significant difference between digital and visual methods in shade selection. Digital method was five times more likely to match the original shade colour compared to visual method.[22] Jivanescu A and coworkers (2010) also conducted a study to determine the inter-observer variability in shade selection for the upper central incisor when using two shade guides (Vita Classical and Vitapan 3D Master) and to compare the results with those of Vita Easy Shade spectrophotometer. They also showed significant difference between digital and visual methods in shade selection.[23]

Another noteworthy observation from this study was that, among the three components of the L*a*b values, all the three groups varied significantly in the L* component, i.e. the Value component in comparison to the control. This is in concurrence to the results of a study done by Sim et al who showed that significant difference that was observed in ΔE for dark shades between the dental personnel was mainly contributed to a disparity in L* values. A

significant difference in ΔL* was observed between dental technicians and Prosthodontists.[17]

The results of the current study should however be considered in the light of the following limitations. Experience of investigators in this study was calculated as number of years from their Third professional year of B.D.S to the current time, i.e. their total clinical experience in dentistry. Further, experience of using the two shade guides used for the study in particular was not kept as a reference in choosing the investigators.

CONCLUSION

Future studies may be directed towards evaluating shade guides of other manufacturers, both manual and digital. A detailed survey on actual practical training in shade matching techniques in academic courses needs to be done as there are no such reports in the literature in recent years. A survey on the usage of digital shade matching devices in clinical practice also needs to be done.

BIBLIOGRAPHY

1. Della Bona A, Barrett AA, Rosa V, Pinzetta C. Visual and instrumental agreement in dental shade selection: Three distinct observer populations and shade matching protocols. Dent Mat J 2009;25:276–281.
2. Yuan JC, Brewer JD, Monaco Jr EA, Davis EL. Defining a natural tooth color space based on a 3-dimensional shade system. J Prosthet Dent 2007; 98:110–9.
3. Kielbassa AM, Beheim-Schwarzbach NJ, Neumann K, Zantner C. In vitro comparison of visual and computeraided pre-and post-tooth shade determination using various home bleaching procedures. J Prosthet Dent 2009; 101:92–100.
4. Lagouvardos PE, Fougia AG, Diamantopoulou SA, Polyzois GL. Repeatability and interdevice reliability of two portable color selection devices in matching and measuring tooth color. J Prosthet Dent 2009; 101:40–5.
5. Stephen J. Chu, Richard D. Trushkowsky , Rade D. Paravina. Dental color matching instruments and systems. Review of clinical and research aspects. J Dent 2010;38: 2–16.
6. Baltzer A, Kaufmann-Jinoian V. The determination of the tooth colors. Quintessenz Zahntech 2004; 30(7):726–740.
7. Okubo SR, Kanawati A, Richards MW & Childressd S. Evaluation of visual and instrument shade matching. J Prosthet Dent 1998; 80(6) 642-8.
8. Tung FF, Goldstein GR, Jang S and Hittelman E. The repeatability of an intraoral dental colorimeter. J Prosthet Dent 2002;88:585-90.
9. SS Meireles, FF Demarco, IS Santos, SC Dumith, A Della Bona. Validation and Reliability of Visual Assessment with a Shade Guide for Tooth-Color Classification. Oper Dent 2008; 33(2):121-6.
10. Van der Burgt TP, ten Bosch JJ, Borsboom PCF, Kortsmit WJPM. A comparison of new and conventional methods for quantification of tooth color. J Prosthet Dent 1990;63:155–162.
11. Hammad IA: Intrarater repeatability of shade selections with two shade guides. J Prosthet Dent 2003;89:50-3.
12. Hassel AJ,Grossmann A, Schmitter M, Buzello ZBA. Interexaminer Reliability in Clinical Measurement of L*C*h* Values of Anterior Teeth Using a Spectrophotometer. Int J Prosthodont 2007;20:79–84.
13. Davison SP, Myslinski NR. Shade selection by color vision defective dental personnel. J Prosthet Dent 1990;63(1): 97-101.
14. Kim-Pusateri S,Brewer JD, Davis EL,Wee AG. Reliability and accuracy of four dental shade-matching devices. J Prosthet Dent 2009; 101:193-9.
15. Dozic A, Kleverlaan CJ, El-Zohairy A, Feilzer AJ, Khashayar G. Performance of five commercially available tooth color-measuring devices. J Prosthodont 2007;16:93-100.
16. Da Silva JD, Park, SE, Weber HP, Ishikawa-Nagai S. Clinical performance of a newly developed spectrophotometric system on tooth color reproduction.
17. J Prosthet Dent 2008;99:361-8.
18. Sim CP, Yap AU, Teo J. Color perception among different dental personnel. Oper Dent 2001;26(5):435-9.
19. Farraj Al-Dosari AF. Reliability of tooth shade perception by dental professionals and patients. Pakistan Oral & Dental Journal 2010; 30(1);244-9.
20. Culpepper WD. A comparative study of shade matching procedures J Prosthet Dent 1970; 24(2): 166-173.

21. Naik AV, Jurel SK, Pai RC. Interoperator variability in shade matching for restoration with two shade guides. IJCD 2011;2(1):30-3.
22. Fernandes A, Lakhani D, Herekar M. A Survey on Variability in Shade Selection by Practicing Dentists. Eur J Esthet Dent 2011; 6:198-204.
23. Judeh A,Al-Wahadni A. A comparison between conventional visual and spectrophotometric methods for shade selection**.** Quint Int 2009;40(9):69-79.
24. Jivanescu A, Marcauteanu C, Pop D, Goguta L, Bratu D. Conventional versus spectrophotometric shade taking for the upper central incisor: a clinical comparative study. Tmj 2010;60:274-9.