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Evaluation of Color and Contour Matching Accuracy with Digital Photography and Direct Vision

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Abstract: The purpose of this study was to compare accuracy of clinical observation and evaluation of digital photographs for shade matching and detection of contour defects. Ten PFM crowns were fabricated using natural teeth. In each crown, a few contour defects were produced. Twenty subjects (7 prothodontists, 7 technician, 6 dental students) with safe color vision make matching color using 3D Master shade guide and detect contour defects and stain requirement. The evaluations were accomplished under standard illumination (illumination of daylight at 11-12 am, No. 6 dental unit, Prosthodotics Department). A photograph of each crown was made with digital camera. After 2-3 weeks the shade selection and detection of contour defects and stain requirement was done but based on digital images. Data were statistically analyzed by SPSS software using paired t-test and Wilcoxon test. Difference of color scores between clinical observation and standard was $\Delta E = 7.41 \pm 13.37$ significantly lower than that between digital image and standard ($\Delta E = 11.14 \pm 13.03$). By clinical observation, there was complete adjustment in incisal/occlusal edge 43.1%, incisogingival height 17.7%, bucolingual contour 16.7% and incorrect line angle 7.7% and by digital evaluation, incisal/occlusal edge 45%, incisogingival height 13.4%, bucolingual contour 6.7% and incorrect line angle 2.4%. Detection of stain requirement completely adjusted in 37.3% by two methods. According to this study, it was concluded that shade selection of PFM crowns and detection of contour defects by clinical observation would have higher accuracy rather than digital image evaluation.

Key words: Color perception, dental veneers, dental esthetics, tooth, PFM, digital image

INTRODUCTION

In spite of recent advances; color matching still remains as one of the most challenging tasks in clinical dentistry. The goal of esthetic dentistry is construction of restoration which has good function and natural appearance therefore, structure that replaces tooth should be acceptable in morphological, visual and biological aspects and external and circumferential form and translucency and color of natural teeth should carefully being duplicated (Hofel *et al*., 2007; Fujita *et al*., 2005; Mojsilovic *et al*., 2002; Cal *et al*., 2006; Van Der Geld *et al*., 2007).

Among translucent, transparent and opaque materials, tooth has a translucent structure and its translucency makes shade matching more difficult. Meanwhile as the increments of white light which reflected from an object (Preston, 1985), determines its color surface characteristics such as gloss, texture and curvature have influence on intensity of light diffused from the object. Therefore, dentists encounter problems in color matching of a restoration by means of color matching criteria's. Recently in so many occasions, color matching process is done by taking digital images and sending it to laboratory (Russell *et al*., 2000; Paravina *et al*., 2002; Lath *et al*., 2007; Yap *et al*., 1999). So by means of modern technologies, reconstruction of a restoration with appropriate form is successful considerably but color matching between teeth and restoration remains a problem.

Teeth color matching by means of computer and spectrophotometer is difficult (Barrett *et al*., 2002; Elter *et al*., 2005) because tooth has translucent, small and irregular structure. Therefore, color matching in restorative dentistry by means of computer is not valid (Fujita *et al*., 2005; Luo *et al*., 2007) and it is shown in a study that colorimeter in multiple shade selection results in same measurements but in 50% measurements were wrong. In other words, this equipment has high repeatability but less accuracy. In according to difficulties

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in relation to form analysis and color matching, defining accuracy of simple and accurate color matching process is of great importance. Therefore, the aim of this study is to compare the accuracy of color matching and contour by means of direct vision and digital photographs.

MATERIALS AND METHODS

Choosing experimental samples: The purpose of this study was to compare accuracy of clinical observation and evaluation of digital photographs after one color matching and detection of contour defects. one patient with at least 1-2 mm buccolingual displacement were chosen (the least thickness required for porcelain fused to metal-PFM-restorations). Before reconstruction of PFM shells, shade selection with 3Dmaster shade guide was performed by a prosthodontics with intact color vision confirmed with Ishihara test under same light source (unite number 6, Prosthetic Department, 11-12 am) and then according to natural teeth, 10 PFM shell were reconstructed on lingualized teeth with T3K (Ticonium USA) and Vita VMK95 (Vident USA) porcelain for replacing on teeth.

A condensation silicon impression was taken and sent to laboratory. The impression was poured in two stages with velmix (Zermakh GMBH) and stone. Molds were trimmed after setting, wax up was done with inlay wax (Dentarume) and were sprued and replaced in metal cylinder and With CD30 investment material and after drying it was replaced in burnout oven.

After casting stage the frames were replaced on die stone and were polished and finished with diamond disc and aluminum oxide mullets and replaced in ultrasonic cleaner. Replacing porcelain, degassing and replacing wash opaque were done according to manufacturer's instructions. These stages were done with Vita VMK95 (Vident USA) porcelain powder. In every shell, some contour defects were designed and applied and these defects were registered. After completing shells, they replaced on tooth structure (Fig. 1a and b).

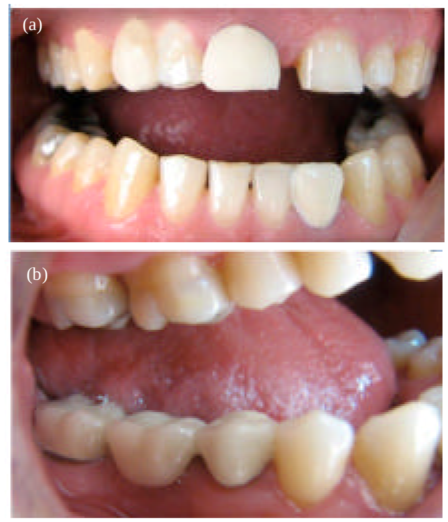

Fig. 1: a, b) Porcelain fused to metal shells on tooth structure

Fig. 2: Dmaster (Vident USA) shade guide

Direct vision assessment: About 20 individuals (7 prosthodontics, 7 laboratory technicians, 6 last year dentistry students) whom healthy visions were confirmed with Ishihara test determined samples color by means of 3Dmaster (Vident USA) shade guide (Fig. 2). They also determined contour deficiency and need for using stains for samples. Evaluation of samples was under same light source (number 6, Prosthetic Department, 11-12 am) and data registered (Appendix, Form no.1).

Digital photograph assessment: Digital photographs of all samples were taken with canon S2 IS (Japan, Canon) digital camera under same light source (number 6, Prosthetic Department, 11-12 am) and after calibration with photoshop and photograph standard printing index. Digital photographs were printed on light sensitive papers (Noritso, Japan).

About 2-3 weeks after direct visual assessments color, contour defects and need for stain were assessed with printed digital photograph of every sample and data registered (Appendix form no.1).

Data registration method: In order to compare two methods of shade selection, results analyzed with SPSS 15th edition statistical software parametric paired t-test and nonparametric Wilcoxon Signed Ranks test were analyzed.

RESULTS AND DISCUSSION

Color: Assessments of registered data shown:

- Color difference between direct vision and standard were ΔE = 7.41±13.37
- Color difference of digital image and standard were ΔE = 11.14±13.03. These differences according to paired t-test with p-value <1% was significant. In other words there is more agreement between direct vision and standard (Table 1)
- Color number difference between direct vision and digital image was ΔE = 7.35±4.85

So, upon difference between direct vision and standard, agreement level in color matching ranked and it was apparent that in direct vision method, there was 18.2% complete agreement (ΔE = 0) meanwhile in digital image method, there was 7.2% complete agreement, according to nonparametric Wilcoxon test, this difference with p-value <1% was significant (Table 2).

Need for staining: In estimating need for stain, researchers couldn't define standard so the results for direct vision were determined as standard. In verifying need for stain, assessments shown that in 37.3%, there was agreement between digital image and direct vision. (Table 3).

Contour defect detection: Data of present study showed that:

- There was complete agreement for incisal/occulusal edges in 43.1% between direct vision and standard. Meanwhile there was 45% complete agreement in digital image method and this difference was not significant from statistical point of view (Table 4)
- Buccolingual contour for direct vision method were in 16.7% and digital images in 6.7% were in complete agreement with standard and this difference was significant with p-value <1% (Table 4)
- For incisogingival height direct vision in 17.7% and digital image in 13.4% there was complete agreement with standard and this difference was significant from statistical point of view (Table 4)
- Error in line angle position for direct vision was 7.7% and for digital images was 2.4%. There was complete agreement with standard and it was significant from statistical point of view with p-value <1% (Table 4)

Goal of dentist in color and other aspect of tooth restoration is the best communication with ceramist for better results and more natural appearance of restoration (Griffin, 2009; Small, 1998). There are problems in this

Table 1: Evaluation of difference in color scores between clinical observation and standard in two methods of digital image and direct vision

Method of color perception	[1]Mean (min-max)	SD	p-value*
Direct vision	7/41 (0-190)	13/37	p = 0/000
Digital image	11/14 (0-183)	13/03	p = 0/000

[1]Mean color difference scores with standard mean; *paired t-test (t = -10/43)

Table 2: Evaluation of color matching accuracy for digital images and direct vision

Color perception method	Number (%) Complete agreement	Partial agreement	No agreement	Sum	p-value*
Direct vision	38 (18/2)	154 (73/7)	17 (8/1)	209 (100)	p=0/000
Digital images	15 (7/2)	132 (63/2)	62 (29/2)	209 (100)	p=0/000

*Wilcoxon Signed Ranks test (Z = - 6/93)

Table 3: Frequency for adjustments in digital image via direct vision

Accuracy score (adjustment)	Number	Percentage
Complete agreement	78	37/3
Partial agreement	74	35/4
No agreement	57	27/3
Sum	209	100

communication because of differences in shade guides with porcelain and there is problem in color masking (Kessler, 1987). Digital imaging is an appropriate method for resolving this problem (Snow, 2007; Gallegos, 2001; Postema and van Overveld, 2000) and a huge step forward in making perfect restorations (Small, 1998; Ward, 2007) therefore dentist's valuable chair time will be saved and it prevents need for reconstructing restoration and more patient satisfaction (Barrett *et al.*, 2002; Mendelson, 2006).

The first part of this research is about evaluating the validity of direct vision in color matching via digital imaging and this is apparent that direct vision has more valid results. Digital imaging errors can be overcome by taking images from different aspects and using SLR camera however, this technique shows 147 partial agreements in 209 total so, it is valuable and in according to results from Terry, Litcher, Postema, Phelan, Griffin. They confirmed digital images as assistant method for color matching in laboratory (Griffin, 2009; Postema and van Overveld, 2000; Phelan, 2002; Lichter *et al.*, 2000; Terry *et al.*, 1999).

Verifying Stain need by digital images in 72.7% was in agreement with direct vision and it confirms Litcher, Snow, Griffin results who call this method valuable for laboratory guidance (Griffin, 2009; Snow, 2007; Lichter *et al.*, 2000). It is different for contour and meanwhile results for incisal edge and incisogingival height were matched with direct vision for buccolingual contours and line angles results were not reliable. This is because of image's two dimensions and buccolingual dimension which cannot be shown in photography. Some researchers such as Phelan and Naylor by using grids and Terry technique and adding stone models to data's help improvement of communication with laboratory (Phelan, 2002).

Table 4: Evaluation of accuracy in contour deficiency perception between direct vision and digital image

Contour deficiency	Deficiency perception method	Number (%) Complete agreement	Partial agreement	No agreement	Sum	p-value*
Incisal-occulusal edge	Direct Vision	90 (43/1)	-	119 (56/9)	209 (100)	p = 0/62 (Z = -0/5)
	Digital Images	94 (45)	-	115 (55)	209 (100)	p = 0/62 (Z = -0/5)
Buccolingual contour	Direct Vision	35 (16/7)	63 (30/1)	111 (53/2)	209 (100)	p = 0/000 (Z = 3/55)
	Digital Images	14 (6/7)	61 (29/2)	134 (64/5)	209 (100)	p = 0/000 (Z = 3/55)
Incisogingival height	Direct Vision	37 (17/7)	43 (20/6)	129 (61/7)	209 (100)	p = 0/33 (Z = - 0/98)
	Digital Images	28 (13/4)	49 (23/4)	132 (63/2)	209 (100)	p = 0/33 (Z = - 0/98)
Lineangle error	Direct Vision	16 (7/7)	50 (23/9)	143 (68/4)	209 (100)	p = 0/002 (Z= - 3/12)
	Digital Images	5 (2/4)	39 (18/7)	165 (78/9)	209 (100)	p = 0/002 (Z= - 3/12)

CONCLUSION

Digital images are good assistants to laboratory technician for determining color and need for stain but for determining contour especially for buccolingual aspect, researchers suggest that using this technique in combination with other techniques such as sending stonemodels to laboratory is more appropriate.

APPENDIX

Form no. 1

Individual comparing name:

Direct vision data □ Digital photograph □

Sample code: Color identified:

Need for stain Vita AKZENT 1-20
1- Incisal Yes □ No □
2- Middle Yes □ No □
3- Cervical Yes □ No □

Contour deficiency

I. Incisal edge/occolusal
  1. Angle
    a. Sharp □ b. Round □ c. Good □

II. Buccal contour
  1. Incisal region
    a. Overcontour □ b. Undercontour □ c. Good □
  2. Middle region
    a. Overcontour □ b. Undercontour □ c. Good □
  3. Corvical region
    a. Overcontour □ b. Undercontour □ c. Good □

III. Incisogingival height
  1. Mesial region
    a. High □ b. Short □ c. Good □
  2. Middle region
    a. High □ b. Short □ c. Good □
  3. Distal region
    a. High □ b. Short □ c. Good □

IV. Lineangle misalignment
  1. Mesial region
    a. Mesially (should be distally)
    b. Distally (should be distally)
    c. Good
  2. Distal region
    a. Mesially (should be distally)
    b. Distally (should be distally)
    c. Good
  3. H.O.C. in cervical region
    a. Incisal (should be cervicaly)
    b. Cervical (should be incisally)
    c. Good

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