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Effectiveness of Calibrated Digital Photography Technique in Dental Shade Analysis

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Research Article

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ABSTRACT

Objectives: Although spectrophotometers are commonly used in shade analysis in dentistry; digital cameras, photographic lighting systems, computer programs and photographs have also become the part of this field. The aim of this study was to compare the success of spectrophotometer and calibrated digital photography on shade selection.

Materials and methods: The 3D-Master toothguide (VITA) with 29 tabs was used for the analyses. The ΔE value was determined with L, a, b values from the middle 1/3 of each sample using a spectrophotometer (Minolta CM -2300D, Konica). Colour calibration was performed using a gray card (white balance, Germany) for digital photographic measurements. Each toothguide in the VITA 3D master toothguide was photographed using a digital camera (Canon EOS 600D), a macro lens (Canon EF 100 mm f 1:2.8), two flash units (Canon MT 24 EX), and a tripod at a distance of 40 cm. Photographs were transferred to image analysis software (Adobe Photoshop CC). Digital photographic measurements created ΔE values using L,a,b values taken from 3 different regions of each sample (middle 1/3, cervical 1/3, and incisal 1/3) and ΔE values obtained from the middle 1/3 of the colour scale using a spectrophotometer were compared.

Results: There were significant differences between L* values of the spectrophotometric analyses and digital measurements in 3 different regions of the tab ($p<0.05$). For the evaluation of ΔE values, Post hoc Bonferroni analysis which was performed between the 3 regions of shade tabs revealed significant difference between the middle (21.92 ± 2.31), incisal (13.67 ± 1.69) and cervical (19.57 ± 2.47) region of the tabs ($p<0.05$).

Conclusions: Spectrophotometer was found to be a more accurate shade determination technique compared to calibrated digital photography.

Keywords: Calibrated Photography, Digital Method, Shade Analysis, Spectrophotometer.

Kalibre Edilmiş Dijital Fotoğraf ile Diş Renk Analizinin Etkinliği

Süreç

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ÖZ

Amaç: Spektrofotometreler diş hekimliğinde renk analizinde yaygın olarak kullanılsa da dijital kameralar, fotoğrafik aydınlatma sistemleri, bilgisayar programları ve fotoğraflar da bu alanın parçası haline geldi. Bu çalışmanın amacı, spektrofotometre ve kalibre edilmiş dijital fotoğrafçılığın renk seçimindeki başarısını karşılaştırmaktır.

Gereç ve Yöntem: Analizler için 29 diş renk örneği bulunan 3D-Master renk skalası (VITA) kullanıldı. Spektrofotometre (Minolta CM-2300D, Konica) ile her bir örneğin orta 1/3 ünden alınan L, a, b değerleri ile ΔE değeri belirlendi. Dijital fotoğrafik ölçümlerde gri kart (White balance, Germany) ile renk kalibrasyonu yapıldı. VITA 3D master renk skalasındaki her bir renk örneği dijital fotoğraf makinesi (Canon EOS 600D), makro lens (Canon EF 100 mm f 1:2.8), twin flaşlar (Canon MT 24 EX) ve 40 cm uzaklığa yerleştirilen bir tripod yardımıyla fotoğraflandı ve fotoğraflar bir görüntü analiz yazılımına (Adobe Photoshop CC) aktarıldı. Dijital fotoğrafik ölçümlerde ΔE değerleri her bir örneğin 3 ayrı bölgesinden (orta 1/3, servikal 1/3 ve insizal 1/3) alınan L,a,b değerleri ile oluşturuldu ve spektrofotometre ile renk skalasının orta 1/3'ünden elde edilen ΔE değerleri ile karşılaştırıldı.

Bulgular: Diş renk örneklerinin 3 farklı bölgesinde spektrofotometrik analizlerin ve dijital ölçümlerin L* değerleri arasında anlamlı farklılıklar saptandı ($p<0.05$). ΔE değerlerinin karşılaştırılması için renk örneklerinin 3 bölgesi arasında yapılan Post hoc Bonferroni analizi, sekmelerin orta (21.92 ± 2.31), insizal (13.67 ± 1.69) ve servikal (19.57 ± 2.47) bölgeleri arasında anlamlı farklılık ortaya koydu. ($p<0.05$)

Sonuçlar: Spektrofotometrenin kalibre edilmiş dijital fotoğrafçılıkla karşılaştırıldığında daha doğru bir gölge belirleme tekniği olduğu tespit edildi.

Anahtar Kelimeler: Kalibre Edilmiş Fotoğrafçılık, Dijital Metod, Renk Analizi, Spectrofotometre.

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Introduction

Esthetic dentistry is usually regarded as the aim of beautiful smile creation.[1] Among all the factors that determine the dental aesthetics, tooth shade matching plays a crucial role in performing the result of the dental therapy.[2-4] Shade matching methods can be divided into two main categories: visual and instrumental. Visual shade matching is a traditional method in dentistry and always be a complicated procedure for dentists during communicating with dental technicians.[5] The specific characterizations of a tooth such as various shades in different portions, translucency or opacities may not be detected by a human eye. In addition, visual shade matching is depending on a wide range factor such as dentist's age, sex, experience, knowledge about tooth shade matching, colour deficiency, eye fatigue and other variables such as different light sources, metamerism and type of the shade guide used.[2,6-12]

The indoor environment of dental office, the type of the light sources, season of the year and almost the time of day are important variables for shade matching. For assisting the visual shade matching, light-correcting devices are used prevalently to reduce metamerism and to permit neutral clearness.[13,14] These instruments correct or decrease the reflected light to approve for a more accurate evaluation of dental translucency and as a result provide more dependable visual shade matching results.[13]

The features in L*a*b* colour space, which is declared in 1976 based on the colour receptors of human eyes,[15] and Hue-Saturation-Value (HSV) colour spaces[16,17] is widely used in dentistry. Most of them measure the differences (ΔE) in L, a*, b* colour features among two tooth shades according to the guide of the American Dental Association for measuring colour differences of dental shades.[15,18,19] Clinical surveillances have declared that a ΔE value greater than 3.7 is graded as an insufficient match in dental shades.[20] There are several limitations of these type of colour measuring instruments such as having a small measuring window which restricting the measurement are of the tooth surface, so the complete tooth surface cannot be detected.[5] Because of the translucency of teeth, these instruments may induce edge loss of the light.[21,22] In addition, they are contemplated for evaluating plain surfaces instead of the geometric distribution of tooth colour .[23]

Unfortunately, the high prices of the colour measurement devices are a handicap for clinicians for daily use. On the other hand, the digital scenes taken with a digital camera and right after determined by using a photo editing software has gathered more attention for evaluation of tooth shades.[24-28] Nowadays, digital cameras have been in a widespread use in dental rehabilitation due to several reasons such as imitation of the patient's nature and transfer the information to the dental technician not with writing but also with an image that tells everything with an objective way. Recent developments in image acquisition and data storage provides a digital, countable, repeatable information. Many studies have indicated the potential of digital cameras for dental shade matching.[24-31]

Although there are some studies evaluating the performance of digital cameras for shade selection,[32-34] effectiveness of calibrated digital photography method is not clear in the literature. The aim of this study was to evaluate the performance of calibrated digital photography method in shade selection and to compare it with the spectrophotometer. The null hypothesis was that no difference would exist between the two shade selection methods.

Materials and Methods

This research protocol was examined and approved by the Institutional Review Board (No:294) and Yeditepe University Non-Interventional Clinical Research Ethics Board (No:5). VITA Toothguide 3D-MASTER (VITA Zahnfabrik) with 29 tabs was used for the analysis. The colour measurements for each tab were performed with a spectrophotometer (Minolta CM-2300D, KONICA) and a digital camera (Canon, EOS 600D).

Spectrophotometric analysis

For spectrophotometric measurements, a white acrylic base holder (Figure 1) was prepared to measure the same point of each tab, as suggested in the literature.[34,35] Before each colour measurement, white calibration of the spectrophotometer was performed according to the manufacturer's recommendation. Each tab was measured 3 times and the mean values were recorded separately for all colour coordinates.

Digital photographic analysis

When measuring with a digital camera, a gray card (White balance, Germany) with a "79" L value was used for calibration. The accuracy of the gray card was checked on the spectrophotometer in which the samples were measured. A phantom maxillary jaw model (G50, KAVO) with a central tooth deficiency was used and a mechanism from a white acrylic material was prepared for fixing both gray card and shade tab to the model (Figure 2).

LED light source (JJC, LED-96) with a 5500 K temperature value was fixed over the model to imitate the daylight and standardize the light comes from the environment. A digital camera (Canon EOS 600D) with a macro lens (Canon EF 100 mm f 1:2.8) and twin flashes (Canon MT 24 EX) were fixed on a tripod. The distance between the shade tab and camera lens was 40 cm. Camera lens was set to be perpendicular to the shade tab as performed in Cal *et al.*'s study.[34] Twin flashes was fixed with a 45° to the tooth surface for cross polarization. To eliminate unwanted reflections on the teeth that are caused by flashes, polar eyes filters were used. Photographs were taken in manual mode and with 1/125 exposure time, F22 aperture, and ISO 100 camera settings (Figure 3).

Figure 1. White acrylic base holder.

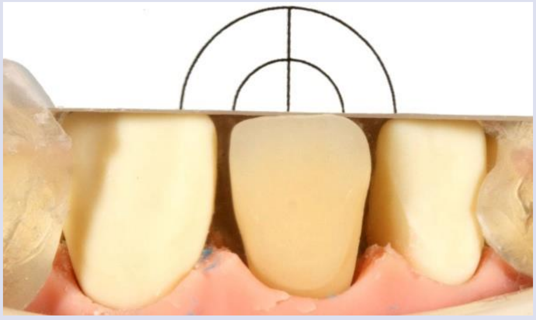

Figure 2. Photoshoot Contrivance.

Figure 3. Photoshooting layout.

Images were transferred to a computer (Macbook Air, Apple Inc.) and opened in an image analyzing software (Camera Raw plugin Adobe Photoshop CC). After calibrating the photographs according to the gray card, "L*a*b*" values on the histogram of application were recorded by looking at the colour of the incisal, middle and cervical 1/3 regions of shade tabs.

ΔE calculation

Digital photographic measurements created ΔE values using L,a,b values taken from 3 different regions of each sample (middle 1/3, cervical 1/3, and incisal 1/3) and ΔE values obtained from the middle 1/3 of the colour scale using a spectrophotometer were compared. The ΔE between the values obtained with the spectrophotometer and digital photography was calculated using the following formula:[15,18,19]

ΔEab = (ΔL2 + Δa2 + Δb2)1/2

Statistical analysis

While evaluating the data of the study, the IBM SPSS Statistics 22 (IBM SPSS, Turkey) was used for statistical analysis. The data were tested for normality using the Shapiro-Wilks test, and the normal distribution of the parameters was demonstrated. The post- hoc Bonferroni test was used to evaluate the differences in mean ΔE values between the different tab regions. Paired samples t-test was used to evaluate the differences between the measurements of the L*a*b* values of the digital and spectrophotometer. $p < 0.05$ was considered statistically significant.

Results

This study evaluated the colour matching accuracy of a calibrated digital photographic technique compared to a spectrophotometer. The tooth colour measurements (L*a*b* values) were collected by the spectrophotometer and digital photography method (Table 1).

The mean and standard deviations of the L*a*b* values of the two methods are shown in Table 2. Paired-samples t-test showed that there were significant differences between the L* values of spectrophotometric analyses and digital measurements in three different regions of the tabs; (middle, incisal, and cervical 1/3) ($p<0.05$). The same statistical analyses also revealed significant differences with respect to the a* values ($p<0.05$). Similar results were observed when b* values were considered ($p<0.05$).

For the evaluation of ΔE values, Post hoc Bonferroni analysis was performed between the 3 regions (Table 3). Results revealed significant difference between the middle (21.92 ± 2.31), incisal (13.67 ± 1.69) and cervical (19.57 ± 2.47) region of the tabs ($p<0.05$).

Table 1. Colour measurements of shade guide examined by two methods.

Tab no.	Spectrophotometer measurements			Digital Measurements								
				Middle 1/3			Incisal 1/3			Cervical 1/3		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
0M1	67.9	1.49	6.29	84	2	6	77	2	5	80	0	0
0M2	67.6	1.68	6.63	84	2	7	77	2	6	79	7	10
0M3	65.1	1.89	8.85	84	2	8	76	2	7	79	5	10
1M1	57.6	2.76	11.18	81	3	11	72	3	11	77	6	13
1M2	59.1	2.67	14.13	81	3	17	72	3	12	81	4	16
2L1.5	57	2.64	12.61	78	3	17	72	3	11	76	6	17
2L2.5	56	3.36	17.08	79	4	24	71	3	15	75	7	23
2M1	57.8	2.77	10.48	79	3	13	70	3	10	77	5	14
2M2	56.7	3.45	14.05	79	4	19	71	4	12	77	7	19
2M3	56.5	4.18	18.13	79	5	26	70	4	16	75	8	26
2R1.5	57.7	3.36	12.1	79	4	16	72	4	10	77	7	16
2R2.5	55.5	4.58	16.47	78	5	23	70	4	14	75	9	24
3L1.5	51.2	3.83	14.27	73	6	23	67	4	15	68	11	23
3L2.5	52.9	4.28	17.06	73	7	28	67	4	16	68	11	28
3M1	53.9	3.57	11.28	74	5	17	67	4	10	69	9	19
3M2	53.1	4.51	14.98	74	6	23	68	5	15	71	11	23
3M3	52.8	5.11	18.4	74	7	30	68	4	17	71	10	30
3R1.5	53.6	4.37	12.86	74	7	20	68	5	13	70	10	21
3R2.5	54.5	5.07	16.75	72	9	30	68	5	17	69	12	29
4L1.5	49.2	4.41	14.07	69	8	25	66	5	14	65	12	23
4L2.5	50.4	4.71	17.63	68	10	33	65	6	18	65	12	31
4M1	51.7	3.75	11.37	69	8	20	65	4	11	65	11	20
4M2	53.6	4.58	15.08	69	9	27	66	5	16	66	12	27
4M3	53.6	5.5	19.11	70	10	35	67	6	19	65	14	34
4R1.5	51.8	4.91	12.9	69	9	23	65	6	14	67	12	24
4R2.5	54	5.41	16.71	69	11	31	66	7	18	67	14	29
5M1	49.5	4.58	11.83	65	10	23	64	6	12	62	13	22
5M2	50.5	5.58	16.19	66	12	32	64	7	18	64	14	31
5M3	50.1	6.87	20.55	66	15	41	64	8	22	64	17	38

Table 2. Comparison of L, a, b measurements of digital photographs and the spectrophotometer.

	L*	a*	b*
	Mean±SD	Mean±SD	Mean±SD
[1]Spectrophotometer	55.2±4.86	4±1,26	14.1±3.55
[2]Digital Middle	74.45±5.8	6.52±3.38	22.34±8.57
[3]Digital Incisal	68.79±3.75	4.41±1.55	13.59±4
[4]Digital Cervical	71.17±5.77	9.52±3.7	22.07±8.13
1-2 p	0.000*	0.000*	0.000*
1-3 p	0.000*	0.001*	0.033*
1-4 p	0.000*	0.000*	0.000*

Paired Samples t test* p<0.05

Table 3. Comparison of the ΔE values according to the measured surface area of the tooth.

	ΔE
	Mean±SD
Midle 1/3	21.92±2.31
Incisal 1/3	13.67±1.69
Cervical 1/3	19.57±2.47
p	0.000*

Post hoc Bonferroni test * p<0.05

Discussion

Shade selection with calibrated digital photography have begun to find a place among current dental applications.[31,36] The aim in these applications is to provide calibration and standardization in photographs which are used for shade selection in dentistry. However, the semi-transparent structure and surface properties of the tooth can prevent this standardization from being fully adjusted. It is useful to know which factors create differences between two separate photographs taken with the same arrangement to make an optimal calibration to the photographs. The amount of light comes to the digital camera may vary and this difference affects the L* parameter which was called as "Value". A gray card, which is considered to reflect 18% of the light falling on it, is used in photography to match the actual colour of the photograph. Since the gray card has exact values, the computer program is interpreted at the same values and the colour tone of the entire image is calibrated.[31]

Although twin flashes that send high-intensity light is used when taking pictures, the ambient light may also have minimal effects on shade selection. In the literature, shade selection under different light sources has been studied and the importance of ideal temperature of daylight (approximately 5500 K) was reported.[17] In addition, the use of polarizing filters has been suggested to prevent unwanted flashes on tooth surface of the camera flash. In present study, polar eyes filters were used for cross-polarization and elimination of unwanted flashes. For the standardization of light comes from the environment with LED light source which has a 5500 K temperature was used.[16,17]

According to the results of the present study, the null hypothesis, no difference would exist between the two shade selection methods, was rejected. There were significant differences between L* a*b* values of the spectrophotometric analyses and digital measurements. In this study, the photographs were calibrated with gray card whose L* value was previously known (L=79). This value was also confirmed in spectrophotometer. Cal *et al.*[34] measured the L*a*b* values on different shade tabs with digital camera and spectrophotometer. They obtained similar results with the present study. However, they reported higher ΔE and L* values. The use of gray card calibration to ensure standardization may be the reason of this difference.

Auxillary processes helped to reduce the ΔE values in this study but remained well above the acceptable limit in the literature[15] which is shown that the colour difference between two objects (ΔE) of < 2 is not discernible to the human eye. The digital cameras show the light entering the sensor by reflecting from the surface of the photographed object, while the spectrophotometers show the amount of light absorbed on the surface. It would be the reason for the extreme difference in lightness (L) values. The fact supports this interpretation that the L values in the incisal regions of shade tabs where the thinner part of the tabs was closer in the results of spectrophotometer and digital camera. Measurements of incisal 1/3 were closer to the spectrophotometer measurements than mid 1/3 and cervical 1/3 area in the present study. Lasserre *et al.*[38] compared the performances of intraoral camera, traditional visual method and spectrophotometer in canine and incisor teeth. They reported that the performance of intraoral camera was better in canine teeth. This result also supports the present study considering that the translucency value of canine teeth is less than incisal teeth.[38]

Choosing a shade by taking a picture of the shade tab might be misleading, and this is one of the limitations of this study. The reason is that the amount of light reflected from the surface and absorbed on the surface of the natural teeth and the shade tabs are different. The comparison of the shade selection techniques using natural teeth or the evaluation of the effect of shade tabs' thickness on the L values of the photographs may be planned in the future studies.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

1. The shade determination with calibrated digital photography could be made from the measurements taken from the incisal 1/3 of the tab, which was the thinnest portion.

2. Spectrophotometer was more accurate shade determination technique when compared to the calibrated digital photography method.

Conflicts of Interest Statement

The authors do not have any financial interest in the companies whose materials are included in this article.

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