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THE EFFECT OF CAMERA TYPE AND COLOR CALIBRATION METHOD ON SHADE MATCHING ACCURACY USING DIGITAL PHOTOGRAPHY

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Abstract

*Shade matching in tooth restoration can be done with two methods, visual method using shade guide and instrumental method using colorimeter or spectrophotometer, both of this methods possess disadvantages that can cause bias in the shade matching result, therefore a new method using digital photography was proposed. The camera that is generally used in digital photography is DSLR camera, but this camera has drawbacks, such as the size of the camera which is large and heavy making it difficult to operate. Other types of digital cameras that are growing rapidly nowadays are mirrorless and smart phone. These two cameras are smaller, lighter, and easier to operate. Due to various parameters that must be standardized in digital photography method, achieving a consistent and adequate photograph is difficult, therefore a corlor calibration method is needed before shade matching are carried out. The color calibration method that can be used in digital photography method is by using cross-polarization filter with and without grey card. The purpose of this study was to determine the effect of mirrorless and smart phone camera with color calibration method using cross-polarization filter with and without grey card on the accuracy of shade matching using digital photography. The research sample was 9 tabs from N-D shade guid. The sample was photographed using a DSLR camera with cross-polarization filter and grey card as the color calibration method, the shade tabs L*a*b* was measured using computer software. The sample group was divided into two groups based on the type of the camera, namely mirrorless and smart phone, then each sample group was further divided into two groups based on the color calibration method, using cross-polarization filter with and without grey card. The value of shade matching accuracy (ΔE) was obtained by comparing the L*a*b* value from the control group with the sample group. The effect of camera type and color calibration method was tested using paired T-test. The result showed that the most accurate color method was in the smart phone camera type group with color calibration method using cross-polarization filter with grey card (1,75±0,30) and the least accurate was in the smart phone camera type group with color calibration method using cross-polarization filter without grey card (27,03±1,19). Paired T-test result showed that there is an effect of the mirrorless and smart phone camera type with color calibration method using cross-polarization filter and grey card on the shade*

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matching accuracy using digital photography with p value p=0,008 (P<0,05), there is an effect of the mirrorless and smart phone camera type with color calibration method using cross-polarization filter without grey card on the shade matching accuracy using digital photography with p value p=0,0001 (P<0,05). There is an effect of the color calibration method using cross-polarization filter with and without grey card using a mirrorless camera on the shade matching accuracy using digital photography with p value p=0,0001 (P<0,05). There is an effect of the color calibration method using cross-polarization filter with and without grey card using a smart phone camera on the shade matching accuracy using digital photography with p value p=0,0001 (P<0,05). The best shade matching methods was the smart phone camera with color calibration method using cross-polarization filter and grey card, the shade matching accuracy of the mirrorless camera when accompanied with color calibration method using a cross-polarization filter and a grey card is clinically acceptable, therefore it is also recommended for clinical shade matching procedure.

***Keywords**: Shade Matching, Digital Photography, Color Calibration Method*

Introduction

The goals in prosthodontic treatment is to restore function, esthetic, and to maintain the stability of oral structure.[1] The Success in restoring the patient esthetic depends on the ability to mimic the natural dentition during the shade matching procedure. Shade matching in tooth restoration can be done with two methods, visual method using shade guide and instrumental method using colorimeter, spectrophotometer, and dental photography. The visual methods are very subjective, and often these techniques are influenced by numerous factor such as: operator experience, light source, environmental condition, and the operator eye health, resulting in inaccurate result.[2-9]

The instrumental method using colorimeter and spectrophotometer provide objective and measurable result in form of color scale, but as the esthetic demand grows, shade matching is not only about color selection, to mimic a natural tooth, it requires communication regarding translucency, opacity, opalescence, fluorescence, as well as surface gloss and textures. Therefore shade matching methods instrumentally using dental photography is more favoured in dental offices.[10] Photographs made with digital camera are able to capture detailed image of the tooth and have been increasingly used in shade matching procedure to communicate with the dental laboratory technician. The camera that is generally used in digital photography is DSLR camera, but this camera has drawbacks, such as the size of the camera which is large and heavy making it difficult to operate, therefore another types of digital cameras were developed such as mirrorless and smart phone. These two cameras are smaller, lighter, and easier to operate than the DSLR.[10-14]

In Mirrorless camera the complex mirror, pentaprism, and dedicated autofocus sensor are removed and the light passing through the lens travels directly to the image sensor. The image sensor in a mirrorless camera then converts the light into an image and displays it in electronic view-finder or on the back liquid-crystal display (LCD). The image sensor function as an auto focus sensor as well. Thus allowing smaller, lighter and mechanically simpler camera. Beside the mirrorless camera, the camera market that grows rapidly is smart phone.[10-14]

In recent years, mobile camera technologies have evolved drastically and at an exceptional rate, today smart phone camera also include features like low light functionality, super-fast autofocus, and optical image stabilization for steady capture. Some models also have manual exposure modes where the photographer can manipulate everything from shutter speed, white balance, focus, and ISO. Particularly in dental photography, due to their various features and characteristics, because of the small size of the camera, its diaphragm and its aperture, a very high depth of field is attained.[10-14]

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Problematically, digital photographs of the natural dentition typically show significant color alterations of teeth and soft tissue when certain diffusers that filter the illuminant are used. Therefore color calibration was required before and after the photo was taken. Color calibration can be done by utilizing reflective cross-polarized light digital photography with a standardized grey card. Cross-polarization filter overcome the disadvantages of flash photography that tend to increase white opacities and reduce specular reflections and light from the camera flash. Standardized grey card help in white balancing the images, nullfying the effect of various diffuser used when taking the photographs.[15-20]

The purpose of this research was to compare the color differences between photography methods taken with different camera types and color calibration methods with the control group to evaluate the effect of camera type and color calibration methods on shade matching accuracy using digital photography. The null hypothesis was that these factors would have no influence on the shade maching accuracy in digital photography.

Materials and Methods

The present study was conducted after obtaining approval from the Ethics Committee of the Universitas Sumatera Utara, Medan, Indonesia. Sample size was determined according to previous studies. N-D shade guide was used as the sample in this research, The shade guide tabs was cleaned first using alcohol then placed on a flat surface photograph was taken using different camera type and color calibration method.

Figure 1. N-D Shade Guide

The control group consisted of acquisition image using digital camera equipped with a DSLR camera (D7000 SLR, Nikkon Corp) equipped with an 105mm lens (AF-S VR Micro Nikkor, Nikkon Corp), a grey card (white balanced, Emulation) was placed parallel with the shade tabs axis. Cross-polarization filter (polar eyes, Emulation) was attached to the Camera, and the camera were flash power 1/1. Shutter speed 1:125, Diafragma f stop 22, ISO 100. The shade guide photo was taken and the result was measured in adobe light room software to get the L*a*b score. The nine shade guide photograph result from the measurement was used as control group.

Figure 2. Control Group Acquisition image

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Group A consisted of acquisition image using digital camera equipped with a mirrorless camera (a6000, Sony), a grey card (white balanced, Emulation) was placed parallel with the shade tabs axis. Cross-polarization filter (polar eyes, Emulation) was attached to the The Camera, and the camera were flash power 1/1. Shutter speed 1:125, Diafragma f stop 22, ISO 100. The shade guide photo was taken and the result was measured in adobe light room software to get the L*a*b score.

Group B consisted of acquisition image using digital camera equipped with a mirrorless camera (a6000, Sony), Cross-polarization filter (polar_eyes, Emulation) was attached to the Camera, and the camera were flash power 1/1. Shutter speed 1:125, Diafragma f stop 22, ISO 100. The shade guide photo was taken without using a grey reference card and the result was measured in adobe light room software to get the L*a*b score.

Figure 3. Mirrorless Camera Acquisition image

Group C consisted of acquisition image using digital camera equipped with a smart phone camera (Realme 7 Pro, Realme), a grey card (white balanced, Emulation) was placed parallel with the shade tabs axis. Cross-polarization filter (Lamp.U, Dentity) was attached to the Camera, and the camera were using light correcting device (Lamp.U, dentity). Shutter speed 1:125 and ISO 100. The shade guide photo was taken and the result was measured in adobe light room software to get the L*a*b score.

Group D consisted of acquisition image using digital camera equipped with a smart phone camera (Realme 7 Pro, Realme), a grey card (white balanced, Emulation) was placed parallel with the shade tabs axis. Cross-polarization filter (Lamp.U, Dentity) was attached to the Camera, and the camera were using light correcting device (Lamp.U, dentity). Shutter speed 1:125 and ISO 100. The shade guide photo was taken without a grey reference card and the result was measured in adobe light room software to get the L*a*b score.

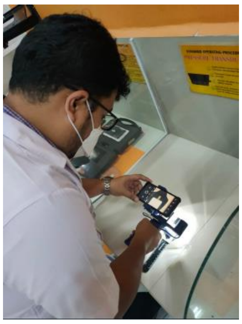

Figure 4. Mirrorless Camera Acquisition image

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The ΔE values between every group compared with the control group were determined and compared with the CIELab system, the following formula was used for obtaining the The ΔE values:

$$\Delta E^*_{ab} = \sqrt{(L_2-L_1)^2 + (a_2-a_1)^2 + (b_2-b_1)^2}$$

The data were evaluated for normality by using the Shapiro-Wilk test (P>.05). After that, the data weew analyzed by using paired T-Test to determine the effect of camera type and color calibration method in shade matching accuracy using digital photography.

Results

The measurement of the marginal gap in the sample was carried out using a computer software (Adobe light room classic CC). In the group A the smallest ΔE values is 1, 87 and the largest ΔE values is 3, 57. In the group B the smallest ΔE values is 6, 23 and the largest ΔE values is 9, 89. In the group C the smallest ΔE values is 0, 59 and the largest the ΔE values is 3, 09. In the group D the smallest ΔE values is 23, 73 and the largest ΔE values is 34, 65. The smallest ΔE from all groups was found in the group C, which was 0, 59, and the largest ΔE was found group D, which was 34, 65.

Figure 5. L*a*b Measurement in Adobe Light room Software

Table 1. The average ΔE values of digital photography image aquisition with mirrorless and smartphone camera with color calibration methods using cross-polarization filter with and without grey card

Description: * smallest value ** largest value

No.	Shade Matching Accuracy (ΔE)			
	Mirrorless		Smart Phone	
	Cross-polarization Filter with Grey card (Group A)	Cross-polarization Filter without Grey card (Group B)	Cross-polarization Filter with Grey card (Group C)	Cross-polarization Filter without Grey card (Group D)
1	3,57**	8,51	2,88	23,73*
2	3,05	8,3	3,09**	34,65**
3	2,47	9,89**	2,54	27,91
4	2,05	6,42	1,23	30,18
5	2,97	6,72	1,86	27,67
6	2,73	8,62	1,43	25,50
7	3,57	6,96	0,59*	24,61
8	3,00	9,62	1,52	23,78
9	1,87*	6,23*	0,64	25,27
±SD	2,81±0,20	7,92±0,46	1,75±0,30	27,03±1,19

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The mean value of the marginal gap was analyzed by univariate test. The average ΔE values in mirrorless camera with cross-polarization filter and grey card is 2, 81, with a standard deviation (SD) of 0, 20. The average ΔE values in mirrorless camera with cross-polarization filter without grey card is 7, 92, with a standard deviation (SD) of 0, 46.

The average ΔE values in smart phone camera with cross-polarization filter and grey card is 1, 75, with a standard deviation (SD) of 0, 30. The average ΔE values in smart phone camera with cross-polarization filter without grey card is 27, 03, with a standard deviation (SD) of 1, 19.

The results of the analysis using Paired T-test showed that there was a significant effect on digital camera type mirrorless and smart phone camera with color calibration methods using cross-polarization filter and grey card on shade matching accuracy (The ΔE values) using digital photography with p value = 0.008 ($p<0.05$) (Table 2)

The results of the analysis using Paired T-test showed that there was a significant effect on digital camera type mirrorless and smart phone camera with color calibration methods using cross-polarization filter without grey card on shade matching accuracy (The ΔE values) using digital photography with p value = 0.0001 ($p<0.05$) (Table 3)

The results of the analysis using Paired T-test showed that there was a significant effect on color calibration methods using cross-polarization filter with and without grey card with digital camera type mirrorless on shade matching accuracy (The ΔE values) using digital photography with p value = 0.0001 ($p<0.05$) (Table 4)

The results of the analysis using Paired T-test showed that there was a significant effect on color calibration methods using cross-polarization filter with and without grey card with digital camera type smart phone on shade matching accuracy (The ΔE values) using digital photography with p value = 0.0001 ($p<0.05$) (Table 5)

Table 2 Effect of Digital Camera type Mirrorless and Smart phone with color calibration methods using cross-polarization filter and grey card on shade matching accuracy.

Digital Camera type	n	$\overline{X}$±SD	p
Mirrorless	9	2,81±0,20	0,008*
Smart Phone	9	1,75±0,30	

Note: * significant ($p < 0.05$)

Table 3. Effect of Digital Camera type Mirrorless and Smart phone with color calibration methods using cross-polarization filter without grey card on shade matching accuracy.

Digital Camera type	n	$\overline{X}$±SD	p
Mirrorless	9	7,92±0,46	0,0001*
Smart Phone	9	27,03±1,19	

Note: * significant ($p < 0.05$)

Table 4 Effect of Color Calibration Methods Using Cross-polarization Filter with and without grey card using Digital Camera type Mirrorless on shade matching accuracy.

Color Calibration Methods	n	$\overline{X}$±SD	p
Cross-Polarization Filter with Grey Card	9	2,81±0,20	0,0001*
Cross-Polarization Filter without Grey Card	9	7,92±0,46	

Note: * significant ($p < 0.05$)

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Table 5. Effect of Color Calibration Methods Using Cross-polarization Filter with and without grey card using Digital Camera type Smart Phone on shade matching accuracy.

Color Calibration Methods	n	$\overline{X}$±SD	p
Cross-Polarization Filter with Grey Card	9	1,75±0,30	0,0001*
Cross-Polarization Filter without Grey Card	9	27,03±1,19	

Note: * significant (p < 0.05)

Discussion

The null hypothesis that digital camera types and color calibration methods would not affect the shade matching accuracy in digital photography was rejected because of thestatistically significant interaction among the study variables.

Analysis using Paired T-test in the effect of digital camera type with color calibration method using cross-polarization filter with and without grey card shows significant result (p<0, 05). Present research shows that to achieve an accurate photo images for color quantification, discipline and consistency in following the photography protocols is required. The photography protocols including the usage of proper color calibration methods, ISO, exposure, aperture, position and distance from the object when taking the images.

Mirrorless camera have similliar settings with DSLR, therefore it is possible to standardize the ISO, shutter speed, and aperture in this camera, meanwhile in the smart phone camera only ISO and shutter speed can be standardized. The difference of the lens that avalaible in mirrorless and smart phone than DSLR camera also contribute in various distance whe taking the photograph.[17-20]

This research also compare two color calibration methods, using cross-polarization filter with and without grey reference card. The goals of calibrating color is to achieve an images that is adequate for shade matching. The Paired T-Test in the effect of color calibration methods using cross-polarization filter with and without grey card on mirrorless and smart phone camera shows significant result (p<0,005). Cross-polarized photography technique uses cross-polarized filters based on a 2 step filtering process with 2 linear polarizer filter, 1 on the flash oriented either horizontally or vertically and 1 on the lens oriented 90 degrees to the flash filter.

The incident light on the teeth from the flash is filtered by the first filter so that only 1 polarization of the light wave passes through. Subsequently, the polarized reflected light from the glossy surface is blocked by the other perpendicular filter, and only back scattered light passes through the filter and is captured by the camera sensor. Grey reference card were used to correct the exposure of objects illuminated by continuous light sources.

The obtained ΔE values from group with color calibration methods using cross-polarization filter and grey card were lower than a clinically acceptable threshold ΔE <3,7, meanwhile ΔE values from group with color calibration methods using cross-polarization filter without grey card were higher than a clinically acceptable threshold ΔE <3,7. In digital photography correcting the color cast of digital images can be done by defining a custom white balance value using a standardize grey card from camera menu or during post production using software.

Without grey card, clinician will not be able to control the white balance value from light exposure from the lighting source, resulting in inaccurate image color.[15-20]

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Present study shows the use of cross-polarized photography with standardized photography and post processing calibration with a grey reference card may yield precise color quantification, regardless of ambient lighting condition.

Conclusion

Shade matching accuracy using smart phone camera with color calibration methods using cross-polarization filter and grey reference card showed the best result. Shade matching accuracy using mirrorless camera with color calibration methods using cross-polarization filter and grey reference card is clinically acceptable.

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