Acta Clin Croat 2024; 63: 403-412
doi: 10.20471/acc.2024.63.02.17

Review

ASSESSMENT OF TOOTH COLOR DIFFERENCE IN DIGITAL PHOTOGRAPHS TAKEN WITH DIFFERENT SMARTPHONES

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SUMMARY – Digital photography has become an indispensable part of modern medicine and dentistry. In the initial stages, digital single lens reflex cameras were used in medicine and dentistry and were considered the golden standard. In recent years, smartphones have become available and enable adjusting of camera settings. The aim of the study was to examine color accuracy on digital photographs taken with a smartphone and the possibility of applying a simple protocol for shooting digital photographs in daily clinical work. The study was conducted on 45 subjects, and a total of 15 JPEG photographs using three smartphones were taken. Five photographs with different lighting modes were taken with each smartphone and the CIE L*a*b* values were measured. Difference in color (dE) was calculated. The results showed that different lighting conditions and different smartphones did affect color values in this study. The CIE L*a*b* values measured on digital photographs using different smartphones and different illuminations differed significantly ($p<0.01$). There was significant difference in color between digital photographs in different illuminations and measurements of the natural teeth ($p<0.01$). Digital photo protocol taken with a smartphone cannot be used as an accurate method for digital determination of tooth color in dentistry.

Key words: *Digital photography; Spectrophotometry; Tooth color; Hue; Value; Chroma*

Introduction

Digital photography has become an indispensable part of modern medicine and dentistry. Initially, its primary role was to document events. In addition to documenting, it has recently been used in diagnostics, planning and monitoring the course and completion of therapy, in communicating with patients and colleagues in the field of the profession, in education, marketing, advertising, and for the purpose of illustrations in publications[1-4]. Digital photography is used in gastroenterology[5], ophthalmology[6,7], plastic surgery[8], emergency medicine[9], surgery[10], orthopedics[2], and radiology[11].

In the initial stages, digital single lens reflex (DSLR) cameras were used in medicine and dentistry and are considered the golden standard to this day[12]. However, in order to take a high-quality photograph, due knowledge and skill are needed to handle such equipment. The main disadvantage of DSLR cameras

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Received December 11, 2023, accepted February 19, 2024

is the size and weight of the equipment itself, and their price[13].

In recent years, smartphones have become available and enable adjusting of camera settings, just as in DSLR cameras. The advantages of using smartphones for taking digital photographs are better affordability, easier handling, and practicality[14]. Fast data connections and high-quality cameras in smartphones have not only made it possible to create high-quality photographs in seconds, without extensive training required in the past to operate a DSLR camera, but have also enabled faster collaboration among clinicians, who are able to send digital photographs to each other[15]. When photographing objects or patients, it is important to ensure a good source of light in order to obtain a good quality photograph. DSLR cameras use different lighting fixtures for this purpose (ring flash, point flash, twin flash).

In order to simplify the protocol for photographing and using digital cameras on smartphones, an additional lighting system called Smile Lite Mobile Dental Photography (MDP) has been developed. The Smile Lite MDP device achieves light continuity, and its light-emitting diodes emit the same temperature of 5500 K as natural daylight and replace the lighting fixtures used in standard DSLR cameras[16]. Newer generations of smartphones used for photography have almost the same options for manually adjusting camera settings as DSLR cameras, such as ISO or sensor sensitivity to light, aperture size (f), white balance (WB), shutter speed (SS), and the very size of the photographs[16]. The accuracy of color reproduction in a photograph is influenced by lighting, type of photo format (raw or JPEG), and type of smartphone[17].

Different smartphones have different image processing algorithms, and essentially, the most accurate color reproduction is needed[14]. Before taking photographs, it is important that the medical professional ensures the patients' consent, ideal conditions for shooting, as well as storing and accessing the photographs obtained [18,19].

The purpose of the study was to examine color accuracy on digital photographs taken with a smartphone and the possibility of applying a simple protocol for shooting digital photographs in daily clinical work.

First null hypothesis was that the International Commission on Illumination (*Commission internationale de l'éclairage*, CIE) CIE L*a*b* values measured on digital photographs obtained using different smartphones and different light conditions did not differ significantly.

Second null hypothesis was that there was no significant difference between CIE L*a*b* values measured on digital photographs using different smartphones and different light conditions, and the same CIE L*a*b* values measured on natural teeth using a spectrophotometer.

Material and Methods

Subjects

The research was conducted on 50 subjects, including those with an upper right central incisor without fillings and caries, without endodontic procedures and prosthetic restorations, without the presence of periodontal diseases or any form of discoloration, and those who did not have fixed orthodontic retainers and had not performed teeth whitening therapy in the past year. Following history taking and clinical examination, subjects who did not meet the given criteria were excluded. Based on the listed criteria, 5 subjects were excluded and 45 ultimately participated in the research (31 female and 14 male).

Materials and procedures

Color measurement using a spectrophotometer

First, the teeth were cleaned with a brush and polishing paste (Proxyt RDA 83; Ivoclar Vivadent, Liechtenstein), and then a retractor (Spandex, Hager & Werken, Duisburg, Germany) was placed to retract the lips and cheeks. The measurement area of the tooth was the central third of the crown of the upper right central incisor. The measurement area, which was also the point of focus during photography, was marked with a stamp and a red waterproof marker. Tooth color was determined digitally using a VITA Easyshade V spectrophotometric device (VITA Zahnfabrik, Bad Sackingen, Germany) (Fig. 1). Before each measurement, the device was pre-calibrated according to the manufacturer's instructions. Spectrophotometric measurement of the tooth color value was expressed in three color parameters, L*a*b*, which were read from the screen on the bottom side of the spectrophotometer (Fig. 2). In this research, the same measurement of tooth color using the spectrophotometer was considered a control measurement.

Mobile dental photography set-up protocol

After determining the color of the teeth, all subjects were photographed, in a standing position with their head upright, leaning against the wall with a retractor placed in their mouth, in the same room without a source of natural light (no windows), with neon lighting (4x120 cm, 36 W, color 765, Philips, Hamburg, Germany), light temperature 5080 K and 500 lux measured with a Chroma-2 colorimeter (Lisun Electronics, Shanghai, China), which research was conducted at the Department of Removable Prosthodontics, School of Dental Medicine, University of Zagreb.

All photographs in this study were taken with a Smile Lite MDP illuminator (Smile Lite MDP, St-Imier, Switzerland). The Smile Lite MDP was placed on a tripod (Metz LS-247, Zirndorf, Germany) to exclude the possibility of the examiner moving his hand when taking photographs at a distance of 15-20 cm from the subject, and also parallel to the vestibular wall of the tooth to avoid possible image distortion. Three different smartphones are placed in the Smile Lite MDP device for photographing frontal teeth. During each swap of smartphones in the device, the retractor was removed from the subjects' mouths to prevent dehydration. The following smartphones were used: Samsung S9+ (Seoul, South Korea), Huawei Pro20 (Shenzhen, Guangdong, China), and iPhone 11 Pro (Apple, Cupertino, CA, USA). All smartphones are set to professional mode when taking photographs. On the iPhone 11 Pro smartphone, professional mode settings were set using the Yammer app (Apple, Cupertino, CA, USA). On the professional mode option, the values of camera sensor sensitivity (ISO), color temperature (WB), aperture (f) and shutter speed (SS) were selected. The adjusted settings on the smartphone cameras are shown in Table 1.

A total of 15 JPEG format photographs were taken in each subject. Five photographs were taken with each smartphone used in this research in five different lighting conditions. The same set and order of photographs was used for each subject, as follows:

1) first photograph was taken with the front light (F) on the Smile Lite MDP switched on;
2) second photograph with the lateral light switched on (L);
3) third photograph with the lateral light on and the diffusers installed (D);
4) fourth photograph with the frontal light on and the polarizing filter installed, the so-called polarized lighting (P); and
5) fifth photograph with the frontal and lateral lights on and the diffusers and polarizing filter installed, the so-called hybrid lighting with full-power LED lighting (H).

Analysis of the photographs

All photographs were transferred to Adobe Photoshop Lightroom 6 (Adobe, San Jose, CA, USA) computer program in Develop Mode. Measurements in the computer program were performed without calibration. The measurement aperture size was set to 0.5x0.5 mm (Digital Colorimeter, Microsoft, Redmond, Washington, USA).

The CIE L*a*b* value was then measured on the tooth, placing the measuring probe exactly in the middle of the red circle previously marked on each upper right central incisor (Fig. 3). The color values obtained in the photographs were then compared with the values obtained with the VITA Easyshade V spectrophotometer.

Color differences (dE) were calculated using the formula: $dE=\sqrt{((L1-L2)^2)+(a1-a2)^2+(b1-b2)^2}$ [20]. Ethical assessment was requested before starting the research. The research was positively evaluated by the Ethics Committee of the Faculty of Dentistry, University of Zagreb. Each research participant voluntarily participated in the research and confirmed their participation in the research by signing an informed consent form. The authors of this paper declare that they were not in conflict of interest during preparation of this paper.

Statistical analysis was performed as follows:

1) difference in L*a*b* values on JPEG photographs regarding 5 different illuminations with all three mobile devices: MANOVA (Bonferroni post hoc correction using ANOVA); and
2) comparison of dEab values on JPEG photographs of three mobile devices in 5 different illuminations with the same L*a*b* values measured using a spectrophotometer: ANOVA (Bonferroni post hoc correction using t-test for dependent samples).

Fig. 1. Tooth color measurement with the Vita Easy Shade V spectrophotometer.

Fig. 2. Vita Easy Shade V spectrophotometer screen.

Fig. 3. Red circle marked on each upper right central incisor.

Table 1. Smartphone camera settings

Smartphone	ISO	Shutter speed	Aperture	WB	Camera resolution
Samsung S9+	100	1/125	1.5	5500 K	12 MP
Huawei Pro20	100	1/125	2.0	5500 K	10 MP
iPhone 11 Pro	100	1/125	2.0	5500 K	12 MP

ISO = sensitivity to light; WB = white balance; K = Kelvin; MP = megapixel

Results

The research results showed that different lighting conditions affected L*a*b* color values in digital photography. It was established that in photographs taken with different smartphones under different lighting conditions, there was a statistically significant difference in all values of color parameters ($F=29.780$; $p<0.01$) (Fig. 4).

When shooting with frontal light, the L*a*b* value was statistically significantly different among all three smartphones, except for the a* value, which was not statistically significantly different between the Huawei and Samsung smartphones, and the b* value between the iPhone and Huawei smartphones ($p>0.05$) (Fig. 4).

When shooting with lateral lighting, the L* values of photographs taken with the Huawei smartphone did not statistically differ from the L* values of photographs taken with the iPhone and L* values of photographs taken with the Samsung smartphone ($p>0.05$) (Fig. 4). The a* values were not statistically significantly different between the Samsung and Huawei smartphones ($p>0.05$) (Fig. 4), whereas b* values were statistically significantly different among all three smartphones ($p<0.05$) (Fig. 4).

In photographs taken with lateral lighting and diffusers installed, the L* values of the tooth color differed statistically significantly among all three smartphones ($p<0.05$) (Fig. 4), whereas the a* value was the only one that did not statistically differ between the Samsung and Huawei smartphones, and the b* value was the only one that was not statistically significantly different between the iPhone and Huawei smartphones ($p>0.05$) (Fig. 4).

In photographs taken with a polarizing filter, the L*a*b* values were not statistically significantly different between the Samsung and Huawei smartphones, which means that when shooting with a polarizing filter, the Samsung and Huawei digital photographs yielded colors that were most similar to one another ($p>0.05$) (Fig. 4), whereas the L*a*b* values on photographs taken with the iPhone smartphone differed statistically significantly when compared to Samsung and Huawei ($p<0.05$) (Fig. 4).

In hybrid lighting, the L* values were statistically significantly different among all three smartphones ($p<0.05$) (Fig. 4), whereas the a* and b* values were not statistically significantly different between Huawei and Samsung smartphones ($p>0.05$) (Fig. 4). The a* and b* values in the photographs taken with the iPhone were statistically different compared to the a* and b* values measured in digital photographs taken with Samsung and Huawei smartphones ($p<0.05$) (Fig. 4).

When CIE L*a*b* values of each smartphone in 5 different lighting modes were compared to the same values obtained using a spectrophotometer and the color different between them was calculated (dEab), statistically significant difference existed in frontal and hybrid lighting mode, with the dEab values obtained by the iPhone smartphone statistically significantly higher compared to Samsung and lower compared to Huawei ($F=29.361$; $dF=2$; $p<0.01$ and $F=7.776$, $dF=2$; $p<0.01$, respectively) (Fig. 5).

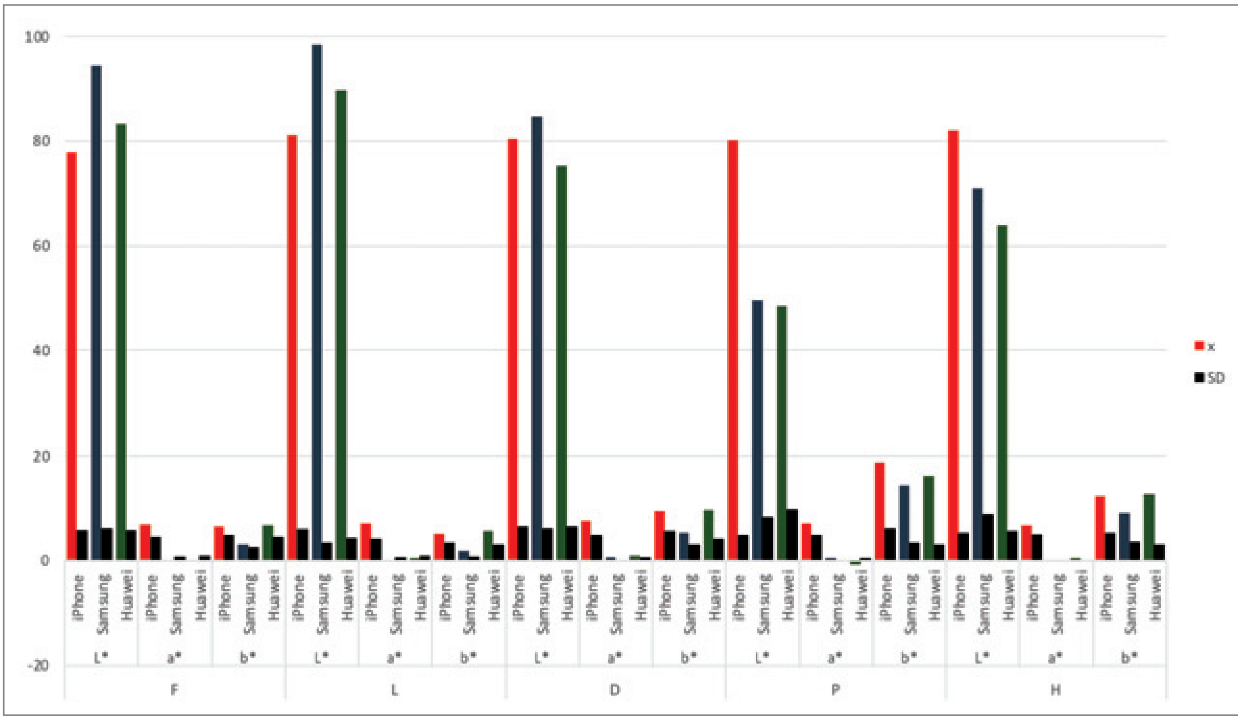

*Fig. 4. Comparison of mean values (x) and standard deviations (SD) of measured uncalibrated L*a*b* values on JPEG photos in 5 different lighting modes with three smartphones (F = frontal; L = lateral; D = diffuser; P = polarizing filter; H = hybrid filter).*

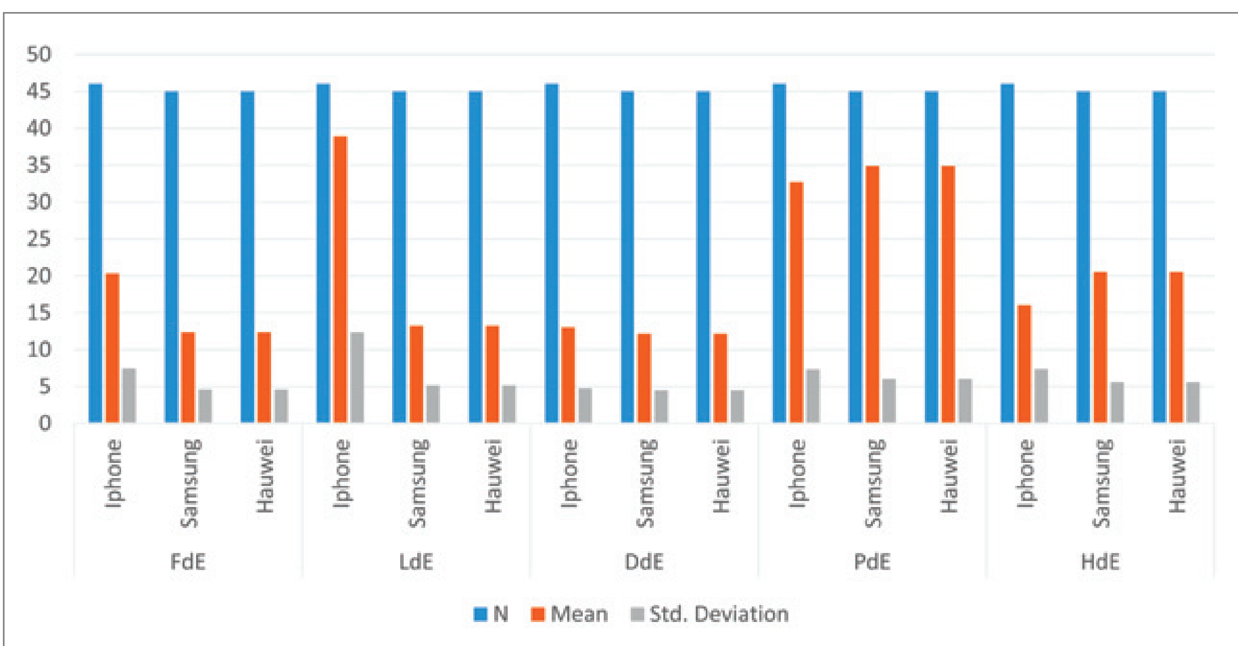

Fig. 5. Comparison of mean values (x) and standard deviations (SD) of measured dEab (between smartphone and values obtained using spectrophotometer) in 5 different lighting modes with three smartphones (F = frontal; L = lateral; D = diffuser; P = polarizing filter; H = hybrid filter).

Discussion

Based on the results of this study, both hypotheses were rejected because statistically significant differences existed between CIE L*a*b* values measured on digital photographs taken using different smartphones and different lighting conditions ($p<0.01$) (Table 2), along with difference between digital and spectrophotometric measurements in some lighting modes.

The results of this research proved that different lighting conditions affected the L*a* b* values in the photographs obtained because the L*a*b* values of the tooth color in digital photographs taken on the same smartphone in different lighting conditions were statistically different ($p<0.01$) (Table 2).

The results of this research also showed that the type of smartphone influenced the L*a* b* values measured in digital photography. By calculating dE values and comparing them between photographs taken using the smartphones, it was found that they were significantly above the acceptability threshold (AT) $\Delta Eab=2.7$.

The results of this research differ from the results published in another study by Soldo *et al.*, where it was proven that there was no statistically significant difference in the L*a* b* values compared to the values measured with a spectrophotometer on photographs taken with an iPhone smartphone with a polarizing filter, in RAW format, without calibration[21]. Differences in the results between these two studies prove that the digital photo format has an influence on the L*a* b* values, considering that in this study, there was a statistically significant difference in the photographs taken with the iPhone smartphone compared to the L*a*b* values measured with a spectrophotometer.

The difference between the two formats of digital photography, JPEG and RAW, exists because the JPEG format is processed and compressed, so it takes up less memory, i.e., the data are smaller, while the RAW format is originally minimally processed, and takes up more memory on the smartphone card and the file itself is larger[22]. In this research, we used JPEG photographs because of their simplicity, less memory consumption, and simpler protocol in everyday work. In this research, the measurement of L*a*b* values in the program was carried out without calibration because of simpler procedure of using digital photographs in daily clinical work.

The results of this research coincide with the results of the research by Shrestha and Poudel, who proved that tooth color measured on digital photographs, taken with a smartphone, could not be used as a reliable method for determining tooth color[23]. The shortcoming of the study by Shrestha and Poudel, in relation to this research, is that they compared the results measuring the value of tooth color with the results measured on digital photographs taken with a DSLR camera, and not with a spectrophotometer, which has been proven to be the most accurate method for digital determination of tooth color[24-26]. Earlier research proved the advantage of using a polarizing filter when taking digital photographs with a DSLR camera and smartphone because the L*a*b* values on photographs taken with a polarizing filter were closest to the values measured with a spectrophotometer[27].

The results of the research by Hein *et al.* showed that by using a polarizing filter to determine tooth color based on a digital photograph taken with a DSLR camera, the measured L*a*b* values were the same as those obtained with a spectrophotometer[28]. The difference between the research by Hein *et al.* and this research is that Hein *et al.* used the RAW photo format, a DSLR camera, and the research was conducted *in vitro*, on extracted teeth, while this research was conducted on photographs taken with smartphones in JPEG format under *in vivo* conditions. Also, Hein *et al.* conducted a photo calibration procedure in a computer program in their research, whereas in this study, the calibration procedure was not performed, which may explain differences in the results[29,30]. The research by Tam and Lee proved that digital photographs taken with a smartphone can be used to determine the tooth color but, unlike our research, they conducted the research *in vitro* and with another smartphone[27].

The research by Boissin *et al.* proved that digital photographs obtained by smartphones could be used as a substitute for digital devices for the purpose of medical telecommunication[31]. Unlike this study, Boissin *et al.* did not measure the exact color in the photo, but only assessed the quality of digital photo through a Likert scale. In the research, they proved that the iPhone smartphone had the best overall ratings in terms of photo quality, based on the answers of the study respondents[31].

In his study, Iqbal proved that digital photographs taken with smartphones can be used for fundus photography in ophthalmology because such photography is cheap, cost effective, portable and a convenient method for retinal imaging. By training young ophthalmology residents and ophthalmic primary caretakers, this retinal imaging technique can be utilized for artificial intelligence, patient diagnosis and educational purposes[6].

In their research, Aruljyothi *et al*. and Phillips *et al*. proved that digital photographs taken with a smartphone could be used in ophthalmology, in the detection of melanoma, and of all the smartphones used, the iPhone smartphone had the closest results with histopathologic findings[32, 33]. Veith *et al.* proved in their research that the smartphone in photography in surgery was a more convenient photographic equipment and produced identical results to the DSLR[34].

The advantage of this research is that it was conducted *in vivo*, which gives more accurate results compared to *in vitro* research. On the other hand, the main disadvantage of this research is that it was conducted on only three different smartphones, and that no calibration procedure was carried out to make the procedure as simple as possible in daily clinical work. Additional research should be conducted that would include newer generations of several types of smartphones, as well as a larger sample of respondents. In future studies in medicine, equipment such as the one used in this research should be included, so that the accuracy of digital photographs taken with a smartphone can be studied for their application in medicine.

Conclusion

The photo-taking protocol for digital photographs taken with a smartphone used in this research cannot be used as an accurate method for digital determination of tooth color in dental medicine. However, this is the simplest method to use in daily clinical work, so color can be viewed as relative and used for communication purposes.

*Table 2. Matching L*a*b* values measured by spectrophotometer and smartphones on JPEG uncalibrated photos at 5 different illuminations*

		iPhone	Samsung	Huawei
F	L*			+
	a*			
	b*			
L	L*	+	+	
	a*			
	b*			
D	L*		+	
	a*			
	b*			
P	L*			
	a*			+
	b*			+
H	L*	+		
	a*			
	b*			

F = frontal; L = lateral; D = diffuser; P = polarizing filter; H = hybrid filter

References

1. Ahmad I. Digital dental photography. Part 2: Purposes and uses. Br Dent J. 2009 May 9;206(9):459-64. doi: 10.1038/sj.bdj.2009.366.
2. Uzun M, Bülbül M, Toker S, Beksaç B, Kara A. Medical photography: principles for orthopedics. J Orthop Surg Res. 2014 Apr 5;9:23. doi: 10.1186/1749-799X-9-23.
3. Casaglia A, De Dominicis P, Arcuri L, Gargari M, Ottria L. Dental photography today. Part 1: Basic concepts. Oral Implantol (Rome). 2016 Jul 23;8(4):122-9. doi: 10.11138/orl/2015.8.4.122.
4. Veselski Krajinović K, Stojadinović T, Pajić Matić I, Matić I, Sekelj A, Mahovne I, Marcikić M, Rotim K. Rare laryngeal hamartoma: a case report. Acta Clin Croat. 2022 Dec;61(4):741-4. doi: 10.20471/acc.2022.61.04.24.
5. Rey JF, El Hajjar A, Gholami R. Photography in digestive endoscopy. In: Pasquali P, editor. Photography in Clinical Medicine. Springer; 2020. p. 24. https://doi.org/10.1007/978-3-030-24544-3_24.
6. Iqbal U. Smartphone fundus photography: a narrative review. Int J Retina Vitreous. 2021;7:44. doi: 10.1186/s40942-021-00313-9.
7. Pavicić-Astalos J, Iveković R, Knezević T, Krolo I, Novak-Laus K, Tedeschi-Reiner E, Rotim K, Mandić K, Susić N. Intralesional tramcinolone acetonide injection for chalazion. Acta Clin Croat. 2010 Mar;49(1):43-8.
8. Kim CH, Most SP. Photography and photodocumentation for the rhinoplasty patient. Clin Plast Surg. 2022 Jan;49(1):13-22. doi: 10.1016/j.cps.2021.07.003.
9. Van Poucke S, Haeghen YV, Vissers K, Meert T, Jorens P. Automatic colorimetric calibration of human wounds. BMC Med Imaging. 2010 Mar 18;10:7. doi: 10.1186/1471-2342-10-7.
10. Howells L, Masters N. A camera in the surgery. Br J Gen Pract. 2013;63(606):42-3. doi: 10.3399/bjgp13X660896.
11. Ramamurthy S, Bhatti P, Arepalli CD, Salama M, Provenzale JM, Tridandapani S. Integrating patient digital photographs with medical imaging examinations. J Digit Imaging. 2013 Oct;26(5):875-85. doi: 10.1007/s10278-013-9579-6.
12. Sampaio CS, Atria PJ, Hirata R, Jorquera G. Variability of color matching with different digital photography techniques and a gray reference card. J Prosthet Dent. 2019 Feb;121(2):333-9. doi: 10.1016/j.prosdent.2018.03.009.
13. Moussa C, Hardan L, Kassis C, Bourgi R, Devoto W, Jorquera G, Panda S, Abou Fadel R, Cuevas-Suárez CE, Lukomska-Szymanska M. Accuracy of dental photography: professional *vs*. smartphone's camera. Biomed Res Int. 2021 Dec 15;2021:3910291. doi: 10.1155/2021/3910291.
14. Hardan L. Advantages of Mobile Dental Photography with Auxiliary Lighting. Chicago: Quintessence Publishing Co.; 2006. p. 47-74.
15. Hunt B, Ruiz A, Pogue B. Smartphone-based imaging systems for medical applications: a critical review. J Biomed Opt. 2021 Apr;26(4):040902. doi: 10.1117/1.JBO.26.4.040902.
16. Hardan LS. Important rules for MDP. In: Hardan L, editor. Protocol for mobile dental photography with auxiliary lighting. Chicago: Quintessence Publishing; 2020. p. 53-65.
17. Boissin C, Fleming J, Wallis L, Hasselberg M, Laflamme L. Can we trust the use of smartphone cameras in clinical practice? Laypeople assessment of their image quality. Telemed J E Health. 2015 Nov;21(11):887-92. doi: 10.1089/tmj.2014.0221.
18. Marsden H, Jaffe W, Matin RN, Wali GN, Greenhalgh J, McGrath E, James R, Ladoyanni E, Bewley A, Argenziano G, Palamaras I. Assessment of accuracy of an artificial intelligence algorithm to detect melanoma in images of skin lesions. JAMA Netw Open. 2019 Oct 2;2(10):e1913436. doi: 10.1001/jamanetworkopen.2019.13436.
19. Mahar PD, Foley PA, Sheed-Finck A, Baker CS. Legal considerations of consent and privacy in the context of clinical photography in Australian medical practice. Med J Aust. 2013 Jan 21;198(1):48-9. doi: 10.5694/mja12.11086.
20. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, Sakai M, Takahashi H, Tashkandi E, Perez Mdel M. Color difference thresholds in dentistry. J Esthet Restor Dent. 2015 Mar-Apr;27 Suppl 1:S1-9. doi: 10.1111/jerd.12149.
21. Soldo M, Illeš D, Ćelić R, Knezović Zlatarić D. Assessment of color parameters on maxillary right central incisors using spectrophotometer and RAW mobile photos in different light conditions. Acta Stomatol Croat. 2020 Dec;54(4):353-62. doi: 10.15644/asc54/4/2.
22. Swarowsky LA, Pereira RF, Durand LB. Influence of image file and white balance on photographic color assessment. J Prosthet Dent. 2023 May 12:S0022-3913(23)00257-3. doi: 10.1016/j.prosdent.2023.04.005.
23. Shrestha P, Poudel S. Comparison between mobile camera and DSLR camera photography for the evaluation of shade of anterior teeth – a cross-sectional study. J Chitwan Med Coll. 2019;9(28):111-9.
24. Lehmann KM, Igiel C, Schmidtmann I, Scheller H. Four color-measuring devices compared with a spectrophotometric reference system. J Dent. 2010;38(1):65-70.
25. Dozic A, Kharbanda AK, Kamell H, Brewer JD. European dental students' opinions about visual and digital tooth color determination systems. J Dent Res. 2011;39(S):23-8.
26. Lazar R, Culic B, Gasparik C, Lazar C, Dudea D. The accuracy of dental shade matching using cross-polarization photography. Int J Comput Dent. 2019;22(4):343-51.
27. Tam WK, Lee HJ. Dental shade matching using a digital camera. J Dent. 2012;40 Suppl 2:e3-10.
28. Hein S, Zangl M. The use of a standardized gray reference card in dental photography to correct the effects of five commonly used diffusers on the color of 40 extracted human teeth. Int J Esthet Dent. 2016;11(2):246-59.
29. Hein S, Modrić D, Westland S, Tomeček M. Objective shade matching communication and reproduction by combining dental photography and numeric shade quantification. J Esthet Restor Dent. 2020. doi: 10.1111/jerd.12641.
30. Hein S, Tapia J, Bazos P. eLABor aid: a new approach to digital shade management. Int J Esthet Dent. 2017;12(2):186-202.
31. Boissin C, Fleming J, Wallis L, Hasselberg M, Laflamme L. Can we trust the use of smartphone cameras in clinical practice? Laypeople assessment of their image quality. Telemed J E Health. 2015 Nov;21(11):887-92. doi: 10.1089/tmj.2014.0221.

32. Aruljyothi L, Janakiraman A, Malligarjun B, Babu BM. Smartphone applications in ophthalmology: A quantitative analysis. Indian J Ophthalmol. 2021 Mar;69(3):548-553. doi: 10.4103/ijo.IJO_1480_20.
33. Phillips M, Marsden H, Jaffe W, Matin RN, Wali GN, Greenhalgh J, McGrath E, James R, Ladoyanni E, Bewley A, Argenziano G, Palamaras I. Assessment of Accuracy of an Artificial Intelligence Algorithm to Detect Melanoma in Images of Skin Lesions. JAMA Netw Open. 2019 Oct 2;2(10):e1913436.doi:10.1001/jamanetworkopen.2019.13436.
34. Veith J, King BW, Moss W, Luo J, Dunklebarger M, Garlick J, Crombie C. Smartphone Use for Patient Photography by Plastic Surgery Trainees. Am Surg. 2023 Dec;89(12):6410-6412. doi: 10.1177/00031348221091943.

Sažetak

PROCJENA RAZLIKE U BOJI ZUBA NA DIGITALNIM FOTOGRAFIJAMA SNIMLJENIM RAZLIČITIM PAMETNIM TELEFONIMA

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Digitalna fotografija postala je neizostavan dio suvremene medicine i stomatologije. U početnim fazama fotoaparati DSLR (*digital single lens reflex*) koristili su se u medicini i stomatologiji i do danas se smatraju zlatnim standardom. Posljednjih godina dostupni su pametni telefoni koji omogućuju namještanje postavaka. Cilj istraživanja bio je ispitati točnost boja na digitalnim fotografijama snimljenim pametnim telefonom i mogućnost primjene jednostavnog protokola za snimanje digitalnih fotografija u svakodnevnom kliničkom radu. Istraživanje je provedeno na 45 ispitanika, a kod svakog ispitanika snimljeno je ukupno 15 fotografija u formatu JPEG pomoću tri pametna telefona. Svakim pametnim telefonom snimljeno je pet fotografija različitim načinima osvjetljenja, a vrijednosti CIE L*a*b* izmjerene su digitalno. Izračunata je razlika u boji (dE). Rezultati su pokazali da različiti uvjeti osvjetljenja i različiti pametni telefoni utječu na vrijednosti boja u ovoj studiji. Vrijednosti CIE L*a*b* izmjerene na digitalnim fotografijama različitih pametnih telefona i svjetlosnih osvjetljenja značajno su se razlikovale ($p<0,01$). Utvrđena je značajna razlika u boji između digitalnih fotografija snimljenih različitim pametnim telefonima u različitim uvjetima osvjetljenja i mjerenja prirodnih zuba pomoću spektrofotometra ($p<0,01$). Protokol za fotografiranje digitalnih fotografija snimljenih pametnim telefonom ne može se primijeniti kao točna metoda za digitalno određivanje boje zuba u dentalnoj medicini.

Ključne riječi: *Digitalna fotografija; Spektrofotometrija; Boja zuba; Nijansa; Svjetlina; Zasićenost*