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Dubravka Knezović Zlatarić, Davor Illeš, Iva Ž.Alajbeg, Maja Žagar

In vivo i *in vitro* procjena ponovljivosti i preciznosti uređaja za određivanje boje zuba VITA Easyshade® Advance 4.0

In Vivo and in Vitro Evaluations of Repeatability and Accuracy of VITA Easyshade® Advance 4.0 Dental Shade-Matching Device

Zavod za mobilnu protetiku Stomatološkog fakulteta Sveučilišta u Zagrebu, Hrvatska
Department of Removable Prosthodontics, School of Dental Medicine, University of Zagreb, Croatia

Sažetak
Svrha: Ovim istraživanjem željela se procijeniti ponovljivost i preciznost uređaja za određivanje boje zuba (VITA Easyshade® Advance 4.0) koristeći se mjerenjima *in vitro* i *in vivo*. **Materijali i metode:** Za procjenu ponovljivosti u mjerenju *in vivo,* uređaj je korišten u središnjem području labijalne površine gornjega desnog središnjeg sjekutića (10 ispitanika, dva mjerenja). Izmjerene su boje B1, A1, A2, A3, C1 i C3. U mjerenju *in vitro* izmjerene su iste boje ključem *Vitapan Classical*. Obavljena su po dva mjerenja u središnjem području svakog zuba. Za procjenu preciznosti uređaja korištena su tri različita ključa *Vitapan Classical*, pri čemu je svaka boja pojedinog zuba u ključu mjerena jedanput. Mjerenja su izražena u CIELab vrijednostima. Za procjenu ponovljivosti *in vivo* i *in vitro* mjerenja samog uređaja, koristili smo se intraklasnim koeficijentom korelacije (ICC). Procijenjene su razlike u oba mjerenja (*in vitro* i *in vivo*). Izračunata je preciznost testiranog uređaja. **Rezultati:** Razlike u srednjim vrijednostima izmjerenih boja u mjerenjima *in vivo* i *in vitro* iznosile su 3,51 E i 1,25 E jedinica. Koeficijenti korelacije (ICC) ponovljivosti uređaja u mjerenju *in vivo* bili su u rasponu od 0,858 do 0,971, a u mjerenju *in vitro* od 0,992 do 0, 994. Točnost testiranog uređaja iznosila je 93,75 posto. **Zaključak:** Unatoč ograničenjima u ovom istraživanju, uređaj za određivanje boje zuba VITA Easyshade®Advance 4.0 omogućio je pouzdano i precizno mjerenje te je zato vrijedno pomagalo u određivanju boje zuba.

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Adresa za dopisivanje
Dubravka Knezović Zlatarić,
Sveučilište u Zagrebu
Stomatološki fakultet
Zavod za mobilnu protetiku,
10 000 Zagreb, Gundulićeva 5
knezovic@sfzg.hr

Ključne riječi
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Uvod

Boja je fenomen vizualne percepcije što reagira na svjetlost koja se odbila ili je prošla kroz neki objekt (1). Prirodna boja zuba rezultat je kombinacije svjetla koje se odbija od površine cakline i svjetla koje se raspršuje i odbija od površine cakline i dentina (2). Na percepciju boje zuba mogu utjecati tri čimbenika – izvor svjetla, objekt koji se gleda i promatrač koji gleda objekt (2).

Dva su načina za određivanje boje zuba – prvi je subjektivan i obavlja se na temelju različitih ključeva boja, a za drugi se upotrebljavaju digitalni uređaji za određivanje boje zuba. Korištenje ključa boja za određivanje boje zuba u stomatologiji je subjektivan proces i na rezultat mogu utjecati mnoge varijable, poput svjetla, kuta gledanja zuba i ključa, te odjeće i šminke, ali i kromatske percepcije stomatologa kao što su prethodno izlaganje oka nekoj boji i metamerizam (3 – 5). Dodatni čimbenici, poput zamora, dobi i emocija, također utječu na interpretaciju promatrača i njegov podražaj na određenu boju (5, 6 – 8). Osim toga, ključ boja nema cijelu paletu nijansi prirodnih zuba (9 – 11).

Uređaji za određivanje boje zuba pojavili su se na tržištu kako bi se smanjili, odnosno prevladali nedostatci tradicio-

Introduction

Colour is a phenomenon of visual perception that responds to the light reflected or transmitted from an object (1). The colour of natural tooth is the result of the combination of light reflected from the enamel surface and light scattered and reflected from both enamel and dentine (2). Three factors can influence the perception of tooth colour – the light source, the object being viewed and the observer viewing the object (2).

There are two ways of assessing colour, one subjective, using different shade guides, and other objective, using different digital shade-matching devices. The use of shade guides to measure shades in dentistry is a subjective process and many variables may affect the results: the surrounding illumination, the angle of view of the tooth and the tab, clothing, make-up and the chromatic perception of the dentist such as previous eye exposure and metamerism (3-5). Additional uncontrolled factors such as fatigue, ageing and emotions also influence the observer's interpretation of colour stimulus (5, 6-8). In addition, shade guides do not repesent the entire gamut of natural teeth colour (9-11).

Dental shade matching instruments have been brought to market to reduce or overcome imperfections and inconsisnalnog načina određivanja boje zuba (5, 12). Oni obuhvaćaju spektrofotometre, kolorimetre i različite kompjutorske sustave za digitalnu procjenu boje.

Spektrofotometri smatraju se najtočnijim, najkorisnijim i najfleksibilnijim uređajima za određivanje boje zuba u stomatologiji (7, 13). Njima se može izmjeriti količina svjetlosne energije koja se odbija od objekta u razmacima od 1 do 25 nm duž vidljivoga spektra (14, 15). U usporedbi s ljudskim okom, odnosno konvencionalnim metodama određivanja boje zuba, ustanovljeno je da je spektrofotometar 33 posto točniji i objektivniji u 93,3 posto slučajeva (5). Neki autori predlažu da se boje određuju i tradicionalno vizualnim tehnikama i digitalno s pomoću uređaja jer se te metode nadopunjuju (16, 17).

Svrha ovog istraživanja bila je procijeniti ponovljivost i preciznost uređaja za određivanje boje zuba (VITA Easyshade® Advance 4.0) mjerenjima *in vivo* i *in vitro*. Nulta hipoteza za ponovljivost samog uređaja bila je da razlika u mjerenjima navedenim uređajem *in vivo* i *in vitro* neće biti pronađena.

Materijali i metode

In vivo mjerenje za procjenu ponovljivosti

Prije mjerenja zubi svih deset pacijenata koji su sudjelovali u istraživanju bili su očišćeni i polirani kako bi se uklonile nakupljene mrlje (Proxyt RDA 83; Ivoclar Vivadent, Liechtenstein). Nakon toga zamoljeni su da polože glavu na naslon stomatološkog stolca i tijekom mjerenja drže usta lagano otvorena. Dobili su također upute da jezik drže u opuštenoj poziciji daleko od gornjih zuba kako bi se spriječilo pogrešno mjerenje. Središnje područje labijalne površine gornjega desnog središnjeg sjekutića svakom je pacijentu izmjereno dva puta u razmaku od jednog sata (slika 1.). Nakon svakog mjerenja popili su vodu kako bi se spriječila dehidracija zuba. Izmjerene su boje B1, A1, A2, A3, C1 i C3. Intraoralni spektrofotometar VITA Easyshade® Advance 4.0 (VITA Zahnfabrik, Bad Säckingen, Njemačka) korišten je za određivanje CIElab vrijednosti. Uređaj za određivanje boja upotrijebljen je prema uputama proizvođača.

In vitro mjerenje za procjenu ponovljivosti

Procjena *in vitro* sastojala se u mjerenjima ključa boja u oralno simuliranom okružju. Tri ključa boja *VITA Classical* (VITA Zahnfabrik, Bad Säckingen, Njemačka) očišćena su sapunom i destiliranom vodom. Za mjerenje boja osigurani su simulirani klinički uvjeti. Istraživanje je obavljeno u istoj sobi u istim uvjetima kao i u postupku *in vivo*.

Iz ključa boja *Vitapan Classical* odabrano je šest zuba (iste boje izmjerene su u mjerenju *in vivo*). Riječ je o bojama s različitim razinama svjetline, zasićenosti i nijansi. Svaki od tih šest zuba izvađen je iz tri različita ključa boja. Mjereni zub postavljen je u sredinu posebno napravljenog akrilatnog držača (GC RelineTM GC Europe NV, Leuven, Belgija), a ostala dva zuba iste boje postavljana su postrance. Mjerenja su obavljena u crnoj kutiji (25 x 14 x 10 cm) koja opona-

tencies of traditional shade matching (5, 12). They encompass spectrophotometers, colorimeters and imaging systems.

Spectrophotometers are amongst the most accurate, useful and flexible devices for colour matching in dentistry (7, 13). They measure the amount of light energy reflected from an object at 1-25 nm intervals along the visible spectrum (14, 15). Compared with observations by the human eye, or conventional techniques, it was found that spectrophotometers offered a 33% increase in accuracy and a more objective match in 93.3% of cases (5). Some authors suggest that instrumental and visual colour matching methods should be used together, as they complement each other (16, 17).

The aim of this study was to evaluate the intra-device repeatability and accuracy of a dental shade-matching device (VITA Easyshade® Advance 4.0) using both *in vitro* and *in vivo* models. The null hypothesis for the intradevice repeatability is that the type of the *in vitro* and *in vivo* model tested presents no difference in the colour measuring and matching of the dental shade-matching device as determined by the colour parameters.

Materials and methods

In vivo model for assessment of repeatability

Before measuring, the teeth of each of the ten patients participating in the study were cleaned and polished to remove any accumulated extrinsic stain (Proxyt RDA 83; Ivoclar Vivadent, Liechtenstein). After the treatment they were instructed to place their heads against the headrest of the treatment chair and to keep their mouths slightly open during measurement. They were instructed to keep the tongue in a relaxed position away from the maxillary teeth during measurement to prevent false measurements. The central region of the labial surface of maxillary right central incisors of each patient was measured twice with an interval of 1 hour (Figure 1). Patients were provided with water after each sequence to prevent dehydration of the teeth. Following tooth colors were measured: B1, A1, A2, A3, C1 and C3. An intraoral spectrophotometer VITA Easyshade® Advance 4.0 (VITA Zahnfabrik, Bad Sackingen, Germany) was used to capture CIELAB colour coordinates. The shade-matching device was operated according to the manufacturer's instructions.

In vitro model for assessment of repeatability

The *in vitro* evaluation was based on measurements of the shade tabs in a simulated oral envionment. Three VITA Classical shade guides (VITA Zahnfabrik, Bad Sackingen, Germany) were cleaned with soap and distilled water. Simulated clinical conditions were created for colour measurement. It was conducted in the same room under the same conditions as in the *in vivo* model.

Six Vitapan Classical tabs (same colours measured in the *in vivo* model) were selected for the study. These tabs created a variety of levels of lightness, chroma and hue. Each of these six shade tabs was removed from three different shade guides. The shade tab to be measured was then placed in the middle of custom made acrylic gingival matrix (GC Reline™ GC Europe N.V., Leuven, Belgium) with shade tabs of ša izgled usne šupljine. Provedena su dva mjerenja na središnjem području svakoga mjerenog zuba u razmaku od jednog sata (slika 2.). Korišten je intraoralni spektrofotometar VITA Easyshade® Advance 4.0 (VITA Zahnfabrik, Bad Säckingen, Njemačka) za određivanje CIELab vrijednosti. Uređaj za određivanje boje upotrijebljen je prema uputama proizvođača u funkciji *tooth color mode*.

In vitro mjerenje za procjenu preciznosti

Zbog točnosti studije svaki zub iz tri ključa boja (VITA Classic; VITA Zahnfabrik, Bad Säckingen, Njemačka) izmjeren je istim uređajem za određivanje boje zuba u istim *in vitro* uvjetima koje smo već spomenuli (slika 3.). Za procjenu preciznosti ukupno je izmjereno 48 zuba (jedno mjerenje). Mjerenje se smatralo ispravnim ako je uređajem za određivanje boje izmjerena ista nijansa koja je označena na zubu iz ključa boja. Preciznost uređaja izražena je kao postotak ukupnog broja podudarnih mjerenja napravljenih za svaku boju (n = 48).

Uvjeti osvjetljenja

Sva mjerenja obavio je jedan iskusni ispitivač prema standardiziranim uvjetima ispitivanja. Prije svakog mjerenja uređaj je kalibriran na svojem bijelom keramičkom bloku. Prema CIE standardu, uvjeti dnevne rasvjete (Just Normlicht, Weilheim der Teck, Njemačka) postavljeni su na 6500 K i 1000 Luxa. Mogućnost utjecaja dnevnog svjetla isključena je jer su mjerenja obavljena u sobi bez svjetla.

Statistička analiza

Izražavanje procijenjenih boja provedeno je uporabom vrijednosti CIELab. Razlike u izmjerenoj boji (dE) izračunate su s pomoću formule:

$$dE = \sqrt{(L1 - L2)^2 + (a1 - a2)^2 + (b1 - b2)^2}$$

Podatci su uneseni u statistički program SPSS 19,0 (SPSS, Chicago, IL, SAD). Za procjenu *in vivo* i *in vitro* ponovljivosti uređaja u mjerenju boje upotrijebljen je t-test za zavisne uzorke te intraklasni koeficijenti korelacije (ICC). Statistička analiza provedena je na razini značajnosti od alpha 0,5.

Rezultati

Srednje L*a*b* vrijednosti svih procijenjenih boja u mjerenjima *in vivo* i *in vitro* prikazane su grafički na slici 4. T-test za zavisne uzorke pokazao je da statistički značajna razlika u ponovljenim mjerenjima postoji samo za *in vitro* izmjerenu L* vrijednost (p = 0,019; tablica 1.). Razlika u *in vitro* izmjerenoj b* vrijednosti također je dosegnula gotovo razinu značajnosti (p = 0,058; tablica 1.).

Razlike u srednjim vrijednostima izmjerenih boja u mjerenjima *in vivo* i *in vitro* iznosile su 3,51 E i 1,25 E jedinica.

ICC-i i mjerenja *in vivo* i *in vitro* na temelju izmjerenih L*a*b* vrijednosti zuba nalaze se u tablici 2. Vrijednosti

the same nominal shade from additional shade guides placed on both sides. The measurements were made inside a black box (25 X 14 X 10 cm) to simulate the oral cavity. Two measurements were made of the central region of each centrally positioned shade tab with an interval of 1 hour (Figure 2). An intraoral spectrophotometer VITA Easyshade® Advance 4.0 (VITA Zahnfabrik, Bad Sackingen, Germany) was used to capture CIELAB colour coordinates. The shade-matching device was operated according to the manufacturer's instructions in tooth colour mode.

In vitro model for assessment of accuracy

For the accuracy study, each shade tab from 3 shade guides (VITA Classical; VITA Zahnfabrik, Bad Sackingen, Germany) was measured once by the shade-matching device under the same *in vitro* conditions mentioned before (Figure 3).

A measurement was considered to be accurate if the shade-matching device selected a shade identical to the shade tab measured. For the accuracy evaluation, a total of 48 colour measurements were made, each measured once. The accuracy of the device was calculated as a percentage of the total number of measurements made for each shade tab (n=48) that were an exact match.

Lightning conditions

All measurements were made by a single trained operator under standardized test conditions. Before any measurement, the device was calibrated on its own white ceramic block. According to the CIE standard, the daylight illumination conditions (Just Normlicht, Weilheim an der Teck, Germany) were set at 6500 K and 1000 Lux. Natural daylight was excluded using a room with no windows.

Statistical analysis

Colour quantification was based on CIE Lab values. Colour differences (dE) were calculated using the formula:

$$dE = \sqrt{(L1 - L2)^2 + (a1 - a2)^2 + (b1 - b2)^2}$$

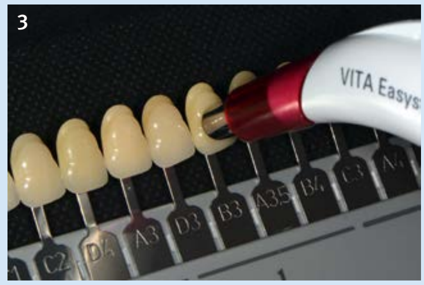
Data were imported into statistical program SPSS 19.0 (SPSS, Chicago, IL, USA). To estimate the *in vivo* and *in vitro* repeatability of the device in measuring and matching tooth colour, paired t-test and t-test for independant samples as well as the intraclass correlation coefficient (ICC) were calculated. All tests were performed at an alpha of .05.

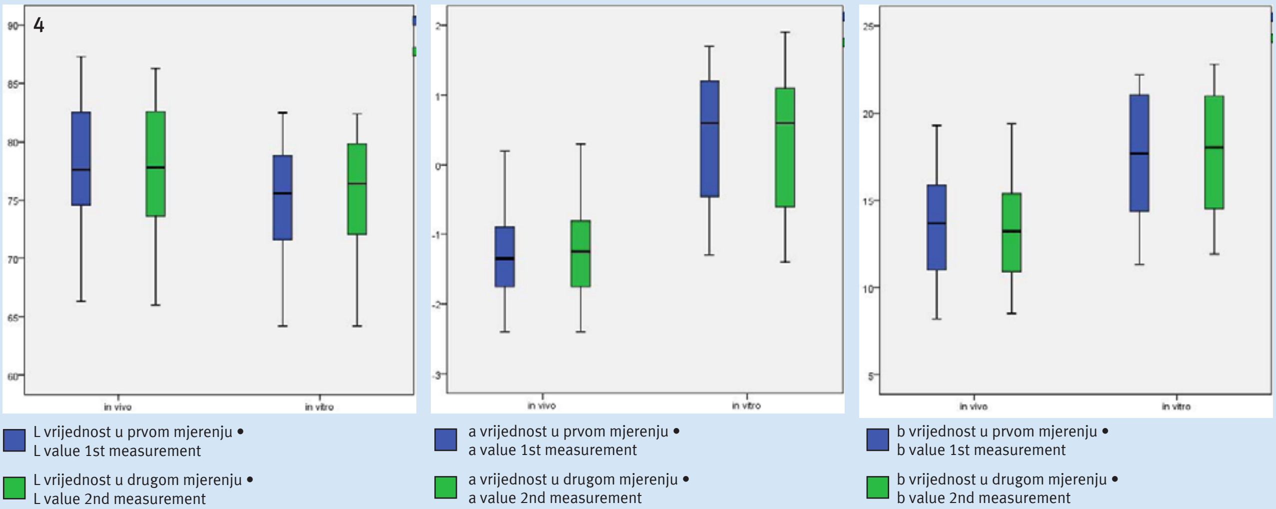
Results

The mean L*a*b* values for both measurements of colours measured in the *in vivo* and *in vitro* models are given graphically in Figure 4. Paired t-tests performed on these values showed significant differences among the repeated measurements only for the *in vitro* measurements of L* component (p=0.019; Table 1). The difference between two *in vitro* measurements for b* component almost reached the level of significancy, too (p=0.058; Table 1).

The mean colour differences (dE) for the *in vivo* and *in vitro* models were 3.51 and 1.25, respectively.

ICCs of *in vitro* and *in vivo* models based on L*a*b* measurements of teeth are shown in Table 2. Intradevice ICCs





Slika 1 Vršak mjerača Easyshade® Advance 4.0 uređaja za određivanje boje zuba u in vivo mjerenju.
Figure 1 VITA Easyshade® Advance 4.0 dental shade-matching device tip positioning for *in vivo* model.
Slika 2. Mjerenje boje umjetnog zuba iz ključa boja postavljenog u individualni akrilatni držač u crnoj kutiji pri in vitro mjerenju.
Figure 2 Measurement of the shade tabs placed in the custom made acrylic gingival matrix in the black box for *in vitro* model measurement.
Slika 3. Testiranje preciznosti mjerenjem boje umjetnih zubi u ključu boja.
Figure 3 Measurement of the shade guide for the accuracy study.
Slika 4. Grafički prikaz CIE L*a*b* vrijednosti izmjerenih zubi u prvom i drugom in vivo i in vitro mjerenju.
Figure 4 Box-and-whisker plots of CIE L*a*b* values of teeth in the *in vivo* and *in vitro* models for the first and second measurements.

Tablica 1. Značajnost razlike CIE L*a*b* vrijednosti unutar in vivo i in vitro mjerenja
Table 1 A significance of differences within *in vivo* and *in vitro* mesurements of CIE L*a*b* color parameters

	Unutar mjerenja (t test za zavisne uzorke) • Within measurements (paired t-test)	
	In vivo t vrijednost/p • In vivo t value/p	In vitro t vrijednost/p • In vitro t value/p
L*	0.7/0.468	-2.5/0.019
a*	-0.8/0.407	0.5/0.612
b*	0.8/0.387	-1.9/0.058

Tablica 2. In vivo i in vitro ponovljivost uređaja pri određivanju boje zuba izražena u interklasnim koeficijentima korelacije (ICCi) temeljena na srednjoj vrijednosti dvaju mjerenja
Table 2 Intraclass correlation coefficients (ICCs) indicating *in vivo* and *in vitro* device repeatability in measuring tooth color, based on the mean of 2 measurements

	Ponovljivost uređaja • Device repeatability	
	In vivo ICC/p	In vitro ICC/p
L*	0.859/<0.001	0.993/<0.001
a*	0.858/<0.001	0.992/<0.001
b*	0.971/<0.001	0.994/<0.001

ICC-a (izražavaju ponovljivost uređaja) bile su vrlo visoke u oba mjerenja (od 0,858 do 0,994), no ipak nešto više zabilježene su u svim komponentama mjerenja *in vitro* (tablica 2).

Pri procjeni preciznosti samo se tri mjerenja zuba iz tri ključa (6,25 %) nisu poklapala (48 zuba iz tri ključa, jed-

(device repeatability) were very high for both models (from 0.858 to 0.994), but higher for all the *in vitro* components (Table 2).

There were only three measurements (6.25%) which were not an exact match in accuracy evaluation (48 shade no mjerenje). Točnost testiranog uređaja VITA Easyshade® Advance 4.0 (VITA Zahnfabrik, Bad Säckingen, Njemačka) iznosila je 93,75 posto.

Rasprava

Boja ispuna znatno utječe na izgled pacijentovih gornjih prednjih zuba te stoga kliničar mora biti vrlo oprezan u procjeni i treba se koristiti pouzdanim alatima (18).

Mjerenja *in vivo* i *in vitro* korištena u ovom istraživanju za procjenu ponovljivosti i preciznosti intraoralnoga spektrofotometra već su prije bila prihvaćena i objavljena (1,19 – 21).

Mjerenja ponovljivosti omogućuju procjenu konzistentnosti uređaja za određivanje boje zuba u provođenju uzastopnih mjerenja iste boje zuba. U Kim-Pusaterijevu istraživanju pouzdanost četiriju različitih uređaja za određivanje boje zuba, uspoređena u kontroliranim *in vitro* uvjetima, iznosila je od 87,4 do 99,0 posto, pri čemu je uređaj Shade Scan bio najmanje pouzdan, a pouzdanost VITA Easyshada iznosila je 96,4 posto (1).

Druga studija *in vitro*, koju su proveli Lagouvardos i suradnici, pokazala je značajno višu ponovljivost uređaja VITA Easyshade u usporedbi s drugim uređajima za određivanje boje samo za L* komponentu mjerenja (ICC = 0,928, p < 0,05), iako su ICC-i za a* i b* vrijednosti bili blago, ali ne i statistički značajno viši (22).

U istraživanju *in vivo* Lehmana i njegovih suradnika o ponovljivosti uređaja VITA Easyshade, ICC za L* iznosio je 0,845, a* = 0,916, b* = 0,914 i E = 2,49 (13).

U ovom istraživanju dobiveni rezultati ne podupiru nultu hipotezu da u mjerenjima *in vivo* i *in vitro* uređajem VITA Easyshade® Advance 4.0 ne postoji razlika u mjerenju boje i njezinih parametara. Rezultati su pokazali da nema statistički značajne razlike između mjerenja *in vivo* i *in vitro*, osim komponente L* u mjerenju *in vitro* (p < 0,001; slika 4, tablica 1). Općenito, L* vrijednost u ovom istraživanju u mjerenju *in vivo* bila je viša nego u postupku *in vitro,* što dokazuje da su prirodni zubi svjetliji od istih boja zuba u ključevima boja (slika 4). Istodobno su a* i b* vrijednosti bile niže u mjerenju *in vivo* (a* komponenta bila je i negativna), što pokazuje da su prirodni zubi više zelenkasti i manje zasićeni u odnosu na iste nijanse u ključu boja (slika 4).

Razlike u izmjerenim bojama u mjerenjima *in vivo* i in vitro iznosile su 3,51 i 1,25 dE jedinica (t = 5,8; p < 0,001). Te su vrijednosti i dalje unutar 50 posto razine prihvatljivosti razlike u boji čija je gornja granica 5,5 dE jedinica, ali dE za mjerenje *in vivo* prelazi granicu od 50 posto prihvatljive vidljive kliničke pogreške (obično iznosi 2,6 – 3,3 dE jedinica) (5,23 – 27). S obzirom na to da je ispitivač u ovoj studiji bio kvalificiran i imao je dobro iskustvo s testiranim uređajem za mjerenje boja te smo postigli standardizirane uvjete i rasvjetu, ovaj nalaz za mjerenje *in vivo* može se pripisati razlikama u morfologiji zubne površine, različitim debljinama slojeva i prozirnosti (transparentnosti) zuba. Iako se ICC-i u mjerenju *in vivo* u ovom istraživanju podudaraju u svim CIE L *a *b* vrijednostima s onima Lehmanovima, naš dE bio je nešto veći i nalazio se na gornjoj razini klinički vidljive razlike koju opaža samo dobro uvježbano oko (23 – 27).

tabs, each measured once). Therefore, the accuracy tested for VITA Easyshade® Advance 4.0 (VITA Zahnfabrik, Bad Sackingen, Germany) was 93.75%.

Discussion

The colour of the restorations is a significant factor affecting dental appearance of maxillary anterior teeth in patients and therefore the clinician has to be very careful in choosing the right one using reliable tools (18).

The *in vivo* and *in vitro* models used in this study to evaluate repeatability and accuracy of an intraoral spectrophotometers have already been accepted and published (1,19-21).

Repeatability measurements enable an evaluation of the consistency of the shade-matching device in making repeated measurements of the same shade tab. In Kim-Pusateri's study the reliability of four different shade-matching devices compared in controlled setting in the *in vitro* model ranged between 87.4% and 99.0%, with ShadeScan having significantly lower reliability and VITA Easyshade with 96.4% (1). Another *in vitro* study, conducted by Lagouvardos et al. reported significantly higher measuring repeatability of VITA Easyshade in comparison to another shade-measuring device only for the L* parameter (ICC = 0.928, p<0.05), alhough ICCs for both a* and b* parameters were slightly, but not significantly higer (22).

Lehman et al. reported that for the *in vivo* model intradevice repeatability for VITA Easyshade ICC for L* was 0.845, a* = 0.916, b* = 0.914 and E = 2.49 (13).

In this study, the results do not support the null hypothesis that the type of the *in vivo* and *in vitro* models tested presents no difference in the colour measuring and matching of the dental shade-matching device as determined by the colour parameters. The results revealed no statistically significant difference within both *in vivo* and *in vitro* measurements with the exception of L* component in the *in vitro* model, (p<0.001; Figure 4, Table 1). Generally, L* parameter for the *in vivo* model was higher than for the *in vitro* model proving that the natural teeth were lighter than the matching shade tabs (Figure 4). At the same time a* and b* components were lower for the *in vivo* model (a* component was even negative) meaning that the natural teeth were more greenish and less saturated in comparisson to the matching shade tabs (Figure 4).

The color difference of the *in vivo* and *in vitro* measurements had an average value of 3.51 and 1.25 dE units, respectively (t=5.8; p<0.001). These values remain below the 50% acceptability level of 5.5 dE units, but exceed the 50% of perceptibility threshold for a clinical mismatch in the *in vivo* model (varies from 2.6 to 3.3 dE units)(5,23-27). Since the examiner in this study was trained and well experienced in the color measurements with the tested device and we achived the standardized conditions and illumination, this finding for the *in vivo* model may be attributed to the tooth variance in surface morphology and the different tooth layers' thickness and transparency. Although ICCs for the *in vivo* model in this study coincided in all CIE L*a*b* compontents with those of Lehman, our dE was slightly higher and therefore got on the upper level of clinically visible difference obvious only to a trained eye (23-27).

S druge strane, u ovoj studiji u mjerenju *in vitro* pronašli smo statističku značajnu razliku između dva mjerenja za L* komponentu, ali istodobno su razlike između mjerenja bile gotovo nevidljive čak i za stručnjaka (mean dE je 1,25) i ICC-i su bili gotovo savršeni (0,992 – 0,994; tablica 2). Ovaj nalaz može se objasniti ujednačenošću tvornički izrađenih plastičnih zuba i teškoćama koje smo imali u procjeni boje na ključu boja. Prema uputama proizvođača za mjerenja *in vivo* koristili smo se modelom *tooth color* za mjerenje boje prirodnih zuba. No, za mjerenja in vitro i procjenu preciznosti (mjerenje ključa boja) bilo je boje upotrijebiti *training mode* koji i služi za mjerenje umjetnih zuba na ključu boja. No postoji problem jer se ovom funkcijom ne mogu izmjeriti CIE L*a*b* vrijednosti te smo se stoga koristili *tooth color* modelom kako bismo izračunali razlike unutar mjerenja i njihove dE. Razlike dobivene u mjerenjima *in vitro* zato mogu biti uzrokovane neodgovarajućim mjerenjem. Browning i suradnici imali su također sličan problem te su objasnili da umjetni zubi u *Vitinu* ključu boja imaju debljinu od 3,5 do 4,0 mm u srednjoj trećini, što je dovoljno da ih se mjeri na isti način kao i prirodne zube (28).

S druge strane, veća raznolikost u mjerenju *in vivo* (srednja vrijednost dE bila je 3,51) može se pripisati jedinstvenosti prizmatične cakline i tubularne strukture dentina prirodnih zuba i važnosti ispravnog pozicioniranja vrha uređaja tijekom mjerenja. U slučaju modela *in vitro* zubi na ključu boja imaju drukčiju, jedinstvenu (uniformiranu) strukturu bez simulacije prizmi ili tubulusa, a tvornički su izrađeni na isti način i zato su razlike u mjerenjima bile konzistentnije.

Preciznost testiranog uređaja u ovom istraživanju iznosila je 93,75 posto. Ovo testiranje omogućuje procjenu valjanosti postupka pri mjerenju zuba poznate boje i važno je jer uređaj treba izmjeriti točne vrijednosti parametara boje bez pretjeranih otklona. U Kim-Pusaterijevu istraživanju preciznost četiriju elektroničkih uređaja za određivanje boja iznosila je u mjerenju *in vitro* od 66,8 do 92,6 posto, a najtočniji je bio *VITA Easyshade* (1). U našem istraživanju preciznost je bila čak nešto viša. U drugim istraživanjima *in vivo* isti uređaj za određivanje boje zuba također je pokazao izvrsnu preciznost (29, 30).

Nedostatak ovog istraživanja jest mali uzorak koji bi se u daljnjim istraživanjima trebao povećati, a glavna okosnica moraju biti mjerenja *in vivo*.

Zaključak

Ovo istraživanje dokazalo je da je ponovljivost mjerenja *in vitro* i *in vivo* gotovo savršena (ICC-i = 0,992 – 0,994; ICC-s = 0,858 – 0,971). Razlike u boji bile su velike, ali na klinički prihvatljivoj estetskoj razini (1,25 – 3,51 dE). Preciznost uređaja za određivanje boje zuba bila je vrlo visoka. Unatoč ograničenjima u ovom istraživanju, uređaj za određivanje boje zuba VITA Easyshade®Advance 4.0 omogućio je

On the other hand, in the *in vitro* model in this study we found statistically significant difference between two measurements for L* component, but at the same time the difference between the measurements was almost invisible, even for the trained eye (mean dE was 1.25) and ICCs were nearly perfect (0.992 to 0.994; Table 2). This finding may be explained by uniformity of prefabricated plastic teeth and difficulties we had in assessing color on the shade-tabs. According to the manufacturer's instructions for the *in vivo* model we used the recomended basic shade measurement mode aimed to measure natural teeth. But for the *in vitro* model (measurement of the shade tabs) it would be better to use „training mode"aimed at measuring artifical shade tabs, and we did so for the accuracy evaluation. There is the problem with this mode because it cannot be used for CIE L*a*b* measurements and we had to use „basic shade measurement" in order to calculate the differences within and between models and their dE. The differences in this model may be caused by inadequate mode. Nevertheless, Browning et al. reported the same issue, explaining that Vita tabs have a thickness of approximately 3.5-4.0 mm in the middle-third, enough to measure them the same way the natural teeth are measured (28).

On the other hand, wider variety of the measurements in the *in vivo* model (mean dE was 3.51) can be attributed to the unique enamel prismatic and dentin tubular structure of the natural teeth and the importance of the correct positioning of the device tip during the measurement. In the case of the *in vitro* model, the teeth on the tabs have different, more uniform structure with no real prismatic or tubular simulation, prefabricated in the same way and therefore the differences in the measurements were more condensed.

For the accuracy evaluation, the null hypothesis that accuracy of the device tested in this study was higher than 90% was proved as it was 93.75%.

Accuracy measurement enables an evaluation of the validity of the shade output when measuring a shade tab of known colour and it is important because instrument must provide the measurements of the true values of color parameters without substential deviation. In Kim-Pusateri study, the accuracy of four electronic shade-matching devices evaluated in the *in vitro* model and ranged between 66.8% and 92.6%, whereas VITA Easyshade demonstrated the greatest accuracy and in our study it was even slightly higher (1). In some *in vivo* studies the same shade-matching device also revealed excellent accuracy (29,30).

The limitation of this study is the small sample which has to be increased in the further studies and the main goal has to be *in vivo* measurement.

Conclusions

This study showed that measuring repeteability was nearly perfect for both *in vitro* and *in vivo* models tested (ICCs=0.992-0.994; ICCs=0.858-0.971; respectively). The colour differences for *in vitro* and *in vivo* models were high, but at a clinically acceptable esthetic level (1.25-3.51 dE units respectively). Accuracy of the shade-matching device was very high. Within the limitations of the study, VITA Eapouzdano i precizno mjerenje te je zato vrijedno pomagalo za određivanje njihove boje.

Sukob interesa

Nije ga bilo.

syshade® Advance 4.0 dental shade-matching device enabled reliable and accurate measurement. It can be a valuable tool for the determination of tooth colours.

Conflict of interest

None declared.

Abstract

Objectives: The objective of this study was to evaluate the intra-device repeatability and accuracy of dental shade-matching device (VITA Easyshade® Advance 4.0) using both *in vitro* and *in vivo* models. **Materials and methods:** For the repeatability assessment, the *in vivo* model utilized shade-matching device to measure the central region of the labial surface of right maxillary central incisors of 10 people twice. The following tooth colors were measured: B1, A1, A2, A3, C1 and C3. The *in vitro* model included the same six Vitapan Classical tabs. Two measurements were made of the central region of each shade tab. For the accuracy assessment, each shade tab from 3 Vitapan Classical shade guides was measured once. CIE L*a*b* values were determined. Intraclass correlation coefficients (ICCs) were used to analyze the *in vitro* and *in vivo* intra-device repeatability of the shade-matching device. The difference between *in vitro* and *in vivo* models was analyzed. Accuracy of the device tested was calculated. **Results:** The mean color differences for *in vivo* and *in vitro* models were 3.51 and 1.25 E units, respectively. The device repeatability ICCs for *in vivo* measurements ranged from 0.858 to 0.971 and for *in vitro* from 0.992 to 0.994. Accuracy of the device tested was 93.75%. **Conclusion:** Within the limitations of the experiment, VITA Easyshade®Advance 4.0 dental shade-matching device enabled reliable and accurate measurement. It can be a valuable tool for the determination of tooth colours.

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Address for correspondence
Dubravka Knezović Zlatarić
University of Zagreb
School of Dental Medicine
Department of Removable Prosthodontics
10000 Zagreb, Croatia
Gundulićeva 5
knezovic@sfzg.hr

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Tooth; Color, Luminescent Measurements; Optical Devices

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