ACTA
STOMATOLOGICA
CROATICA
www.ascro.hr

Acta stomatol Croat. 2016;50(1):34-39.
DOI: 10.15644/asc50/1/5

IZVORNI ZNANSTVENI RAD
ORIGINAL SCIENTIFIC PAPER

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In vivo procjena pouzdanosti mjerenja ispitivača uređajem za određivanje boje zuba VITA Easyshade® Advance 4.0

In Vivo Evaluations of Inter-Observer Reliability Using VITA Easyshade® Advance 4.0 Dental Shade-Matching Device

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Sažetak
Svrha: Procijeniti pouzdanosti mjerenja ispitivača uređajem za određivanje boje zuba. **Materijali i metode:** Istraživanje je provelo četvero ispitivača dobro uvježbanih za određivanje boje zuba i rukovanje uređajem za određivanje boje zuba. Odredili su boju zuba i CIE L*a*b* vrijednosti na zdravim i intaktnim gornjim desnim središnjim sjekutićima desetero pacijenata. Svaki pojedini ispitivač mjerio je dva puta središnji dio labijalne plohe svakoga pojedinog ispitivanog zuba s pomoću uređaja za određivanje boje zuba VITA Easyshade® Advance 4.0. Izmjerena je pouzdanost između ispitivača i izračunata su odstupanja u L*a*b* i E vrijednostima. Pouzdanost između ispitivača analizirana je intraklasnim koeficijentima korelacije. **Rezultati:** Jednosmjerni ANOVA test nije dokazao između četvero ispitivača statistički značajnu razliku u određivanju boje zuba u svim mjerenjima ($p > 0,05$). Vrijednosti ΔE iznosile su od 3,018 do 5,234. Statistički značajna razlika između ispitivača nije pronađena ($p > 0,05$), iako su postojale male razlike. Vrijednosti ICC-a između ispitivača bile su visoke i kod svih su se kretale od 0,651 do 0,992 . **Zaključak:** Rezultati mjerenja pokazali su prihvatljivu pouzdanost mjerenja svih ispitivača uređajem za određivanje boje zuba VITA Easyshade® Advance 4.0. Za pravilno određivanje boje zuba, osim digitalne tehnologije, potrebni su i iskusni ispitivači.

Zaprimljen: 17. studenoga 2015.
Prihvaćen: 1. ožujka 2016.

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Ključne riječi
zubi; boja; optički uređaji

Uvod

Postići zadovoljavajući osmijeh jedan je od glavnih problema u estetskoj stomatologiji, a zahtjevi pacijenata za njihovim sve boljim i ljepšim izgledom zuba potiču dentalnu industriju na kontinuirano podizanje ljestvice kad je riječ o materijalu, tehnici i tehnologiji.

Posljednja istraživanja pokazala su zadovoljstvo pacijenta da na njihov dentalni izgled najviše utječe boja zuba (1 – 3). S druge strane, razlikuje se klinička i pacijentova procjena estetskih parametara, poput boje zuba ili nadomjestka (4). Samorodnitzky-Naveh i suradnici dokazali su da laici ocjenjuju boju svojih zuba tamnijom negoli stručne osobe te da žene procjenjuju boju zuba preciznije od muškaraca (5).

Da bi se izbjegle razlike između kliničareva i pacijentova subjektivnog određivanja boje zuba na koje utječe okolno osvjetljenje, kut promatranja zuba i *ključa* boja**,** odjeća, šminka i kromatska percepcija stomatologa zbog prijašnjeg izlaganja očiju te metamerizam, umor, starost i emocije, na tržištu su se pojavili uređaji za određivanje boje zuba. Ti aparati smanjuju ili prevladavaju nedostatke i nedosljednosti tradicionalnog načina određivanja boje zuba (6 – 11). Riječ je o različitim instrumentima i softverima. Spektrofotometri su među najtočnijima, najkorisnijima i najfleksibilnijim instrumentima za određivanje boje zuba u stomatologiji (10, 12). Oni

Introduction

Providing an esthetically pleasant smile is one of the main concerns in esthetic dentistry and the patients' demands for an improved dental appearance have prompted the industry to continuously raise the bar with regard to materials, techniques and technology.

Recent studies have shown that the tooth color is one of the most important parameters determining the patients' satisfaction with their dental appearance (1-3). On the other hand, clinical assessment and the patient's evaluation of esthetic parameters, including teeth or restorations' color, may also differ (4). Samorodnitzky-Naveh et al. have proven that lay people evaluate their teeth darker in comparison to the professionals, and that women assessed tooth shades more accurately than men (5).

In order to avoid the differences arising from both the clinicians and patients' subjective visual color determination affected by 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, fatigue, ageing and emotions, dental shade matching instruments have been brought to the market to reduce or overcome imperfections and inconsistencies of traditional shade matching (6-11).

mjere količinu svjetlosne energije koja se odbija od objekta u intervalima od 1 do 25 nm, a unutar vidljivog spektra (13, 14). U usporedbi s mjerenjima boje ljudskim okom i konvencionalnim tehnikama utvrđeno je da su spektrofotometri povećali točnost (preciznost) 33 posto i u 93,3 posto slučajeva su objektivniji (8). Neki autori predlažu da se instrumentalne i vizualne metode određivanja boje zuba upotrebljavaju zajedno jer se međusobno nadopunjuju (15, 16).

Svrha ovog istraživanja bila je u uvjetima *in vivo* procijeniti pouzdanost mjerenja četvero ispitivača uređajem za digitalno određivanje boje zuba (VITA Easyshade® Advance 4,0). Nulta hipoteza glasila je da se neće razlikovati boje koje će izmjeriti četvero ispitivača istim uređajem za određivanje boje.

Materijal i metode

U istraživanju je sudjelovalo desetero pacijenata s potpuno zdravim i intaktnim gornjim prednjim zubima. Isključeni su bili oni s diskoloracijama, mrljama, istrošenim zubima, kompozitnim ispunima, ljuskama i krunicama. Pacijenti su položili glavu na naslon stomatološkog stolca i tijekom mjerenja lagano otvorili usta. Da bi se izbjegle pogreške, zamoljeni su da opuste jezik i odmaknu ga od gornjih zuba. Pojedini ispitivač svakom je pacijentu u razmaku od jednog sata izmjerio središnje područje labijalne plohe gornjega desnoga središnjeg sjekutića. Da im između mjerenja zubi ne bi dehidrirali, pacijenti su pili vodu. Izmjerene su sljedeće boje: B1, A1, A2, A3, C1 i C3. Za mjerenja je korišten intraoralni spektrofotometar VITA Easyshade® Advance 4,0 (VITA Zahnfabrik, Bad Sackingen, Njemačka) (slike 1. i 2.). Uređaj za određivanje boje zuba korišten je prema uputama proizvođača.

Svi ispitivači u ovom istraživanju uvježbali su korištenje uređaja za određivanje boje zuba u standardnim uvjetima. Prije svakog mjerenja uređaj je bio kalibriran na svojem bijelom keramičkom bloku i korišten je u funkciji *pojedinačni zub*.

Uvjeti osvjetljenja

Prema standardima CIE, uvjeti osvjetljenja (Just Normlicht, Weilheim an der Teck, Njemačka) postavljeni su na 6500 K, 1000 luksa. Mogućnost utjecaja dnevnog svjetla isključena je, jer su se mjerenja obavljala u sobi bez svjetlosti.

Statistička analiza

Izražavanje procijenjenih boja provedeno je uporabom CIE L*a*b* vrijednosti. Izračunate su i razlike u boji (E). Podatci su obrađeni u statističkom programu SPSS (19.0; SPSS, Chicago, IL, SAD). Za procjenu pouzdanosti mjerenja ispitivača u uvjetima *in vivo* korišteni su jednosmjerni ANOVA test (Bonferroni Post Hoc test) i intraklasni koeficijenti korelacije (ICC). Statistička analiza obavljena je na razini značajnosti od alpha 0,5.

They encompass different instruments and software. Spectrophotometers are amongst the most accurate, useful and flexible instruments for color matching in dentistry (10, 12). They measure the amount of light energy reflected from an object at 1-25 nm intervals along the visible spectrum (13,14). 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 (8). Some authors suggest that instrumental and visual color matching methods should be used together since they complement each other (15,16).

The aim of this study was to evaluate the inter-observer reliability of dental shade-matching device (VITA Easyshade® Advance 4.0) using an *in vivo* model. The null hypothesis was that the color assessment tested shows no difference between four observers using the same dental shade-matching device.

Materials and methods

Ten patients with completely healthy and intact maxillary anterior teeth participated in this study. Those with discolorations, stains, evidence of visible tooth wear, composite fillings, veneers of crowns on investigated teeth were excluded. The patients were instructed to place their heads against the headrest of the dental 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 each patient's right maxillary central incisor was measured twice by each observer with an interval of 1 hour, and the average value was considered. Patients were provided with water after each sequence to prevent dehydration of the teeth. The following 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 (Figures 1 and 2). The shade-matching device was operated according to the manufacturer's instructions.

All operators in this study were well trained in color assessment and handling of the dental shade-matching device under standardized test conditions. Before any measurement, the device was calibrated on its own white ceramic block and it was used in 'tooth single' mode.

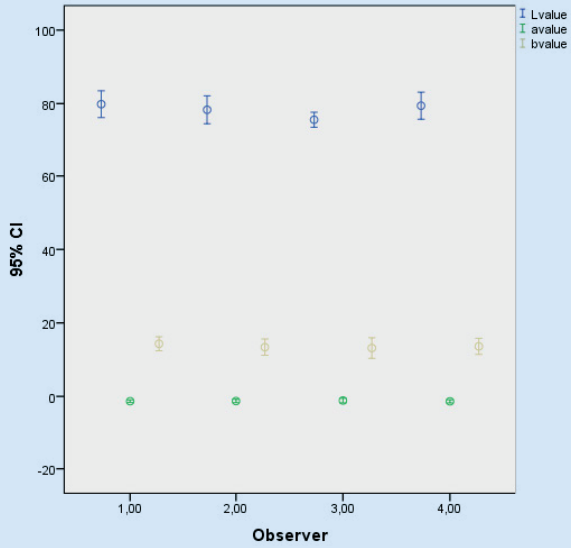
Light test conditions

According to the CIE standard, the daylight illumination conditions (Just Normlicht, Weilheim an der Teck, Germany) were set at 6500 K and 1000 Lux, of 93 foot-candles. Natural daylight was excluded using an optical opaque louver.

Statistical analysis

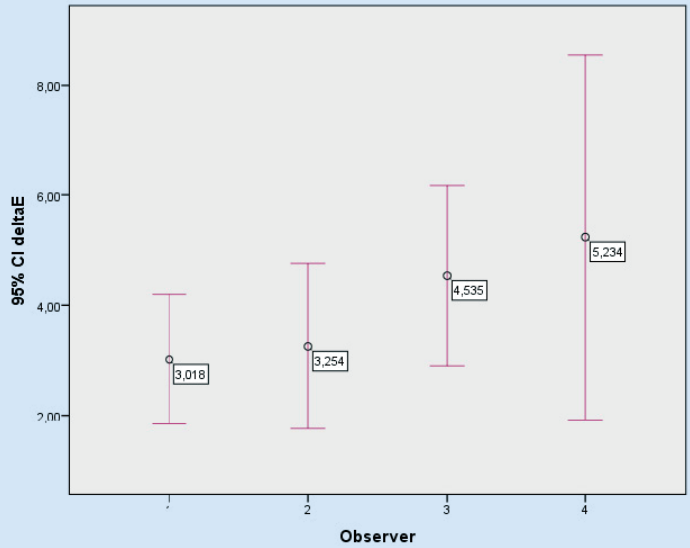
Color quantification was based on CIE L*a*b* values. Color differences (E) were calculated. Data were imported into statistical program SPSS 19.0; SPSS, Chicago, IL, USA). To estimate the *in vivo* inter-observer reliability in measuring and matching tooth colors, one-way ANOVA (Bonferroni Post Hoc test) and intraclass correlation coefficients (ICCs) were calculated. All tests were performed at an alpha of .05.

Slika 1. Izmjerena boja zuba izražena u Vita klasičnim i 3D Master vrijednostima
Figure 1. Measured dental color expressed in Vita classical and 3D Master values
Slika 2. CIE LCh i L*a*b* vrijednosti izmjerene boje zuba
Figure 2. CIE LCh and L*a*b* values of the measured dental color.



CI = interval pouzdanosti / confidence interval

Slika 3. Stupci CIE L*a*b* vrijednosti mjerenja svih četvero uvježbanih ispitivača
Figure 3 Error bars of CIE L*a*b* vaules measured by four well trained observers



CI = interval pouzdanosti / confidence interval

Slika 4. Stupci delta E vrijednosti mjerenja svih četvero uvježbanih ispitivača
Figure 4 Error bars of delta E vaules measured by four well trained observers

Rezultati

Srednje vrijednosti L*a*b* mjerenja svih četvero ispitivača na deset gornjih desnih središnjih inciziva izmjerenih u uvjetima *in vivo,* grafički su prikazane na slici 3. Jednosmjerni ANOVA test nije dokazao značajnu razliku u svim izmjerenim vrijednostima četvero ispitivača ($p > 0,05$).

Srednje vrijednosti razlika u boji istih mjerenja prikazane su grafički na slici 4. Vrijednosti ΔE u ovom istraživanju iznosile su od 3,018 do 5,234. Nije pronađena statistički značajna razlika između ispitivača ($p > 0,05$), iako su postojale male razlike. Intraklasni koeficijenti korelacije za L*a*b* vrijednosti u *in vivo* prikazani su u tablici 1. Intraklasni koeficijenti korelacija između ispitivača bili su visoki kod svih ispitivača i kretali su se od 0,651 do 0,992 (tablica1.).

Results

The mean L*a*b* values for measurements of 10 right maxillary central incisors measured in an *in vivo* model by four different observers are shown graphically in Figure 3. One-way ANOVA showed no statistically significant differences in color measurement of four observers in all the measured values ($p>0.05$).

The mean color differences for the same measurements are shown graphically in Figure 4. Delta E values in this study ranged from 3.018 to 5.234. Although some small differences existed, a statistically significant difference between the observers was not found ($p>0.05$).

ICCs of *in vivo* model based on L*a*b* measurements of teeth are shown in Table 1. Inter-observer ICCs were very high for all observers (from 0.651 to 0.992) (Table 1).

Tablica 1 Intraklasni koeficijenti korelacije (ICCi) između dva mjerenja prikazuju pouzdanost mjerenja boje zuba u uvjetima *in vivo*
Table 1 Intraclass correlation coefficients (ICCs) indicating in vivo reliability in measuring tooth color, based on mean of 2 measurements

	Observer			
	1 ICC/p	2 ICC/p	3 ICC/p	4 ICC/p
L*	0.930/<0.001	0.929/<0.001	0.857/<0.001	0.651/<0.001
a*	0.944/<0.001	0.906/<0.001	0.742/<0.001	0.992/<0.001
b*	0.966/<0.001	0.980/<0.001	0.971/<0.001	0.971/<0.001

Rasprava

Danas je u modernoj stomatologiji iznimno važno točno odrediti boju zuba kako bi se pri izradi nadomjestka postigao isti efekt. U našem prijašnjem istraživanju *in vivo* i *in vitro* testirali smo ponovljivost i točnost uređaja za određivanje boje zuba (VITA Easyshade® Advance 4,0) (17). Rezultati su pokazali veće L* i niže a* i b* vrijednosti u modelima *in vivo,*u odnosu na modele *in vitro*, sa srednjom razlikom od 3,51 i 1,25 Δ E jedinica (p < .001).

ICC-i za ponovljivost mjerenja uređaja u istraživanju *in vivo* iznosili su od 0,858 do 0,.971, za *in vitro* od 0,992 do 0,994, a točnost uređaja bila 93,75 posto (17).

Prije početka određivanja boje zuba važno je ne samo testirati uređaj, nego testirati i nezavisne ispitivače slažu li se njih dvoje ili više njih o tome što vide. Na taj način, ako se postigne zadovoljavajuća razina pouzdanosti između ispitivača, svaki od njih može samostalno obavljati mjerenja možda u različitom vremenu i /ili na različitim mjestima, a njihova se mjerenja mogu kombinirati u statističkoj analizi.

U ovom istraživanju nulta hipoteza bila je da ne postoji razlika između ispitivača u određivanju boje zuba ako se koriste istim uređajem (za određivanje boje zuba). Iako su postojale male razlike, naši rezultati u svim mjerenjima nisu pokazali statistički značajnu razliku u određivanju boje zuba između ispitivača (p > 0,05) (slika 3.), vrijednosti Δ E bile su u rasponu od 3,018 do 5,234 (p > 005) (slika 4.), a ICC-i ispitivača bili su visoki (tablica 1). Zbog toga je hipoteza prihvaćena.

L*a*b* vrijednosti kod svih su ispitivača bile konzistentne, ali su vrijednosti ΔE bile više. Prešle su granicu od 50 posto prihvatljive vidljive kliničke pogreške (2,6 – 3,3 E jedinice), ali su još uvijek ostale ispod 50 posto razine prihvatljivosti razlike u boji od 5,5 E jedinica (8,18 – 21). Četvrti ispitivač imao je najveću vrijednost Δ E (5,234). Budući da je bila na gornjoj granici prihvatljivosti, a njegovi ICC-i za L vrijednosti najniži (65 %), odlučili smo ga isključiti iz daljnjeg istraživanja (slika 4., tablica 1.). Kako je svih četvero ispitivača u ovom istraživanju bilo dobro uvježbano u određivanju boje zuba ovim uređajem, a u standardiziranim uvjetima i osvjetljenju, ovaj se nalaz može pripisati promjenama u morfologiji površine zuba i položaju vrška mjernog uređaja na srednjoj trećini svakoga zuba.

Dosad je već dokazano da postoje razlike u pouzdanosti između ispitivača i da su ovisne o vrsti zuba. Lasserre i suradnici dokazali su da su mjerenja ispitivača na očnjacima točnija od onih na središnjim sjekutićima, te objasnili da se pogreške na središnjim sjekutićima pojavljuju zbog njihove visoke prozirnosti (22). U ovom istraživanju određivali smo boju zuba samo na središnjim sjekutićima i uzorak je bio mali (samo 6 boja), pa je zato teško uspoređivati rezultate.

Drugo objašnjenje za pogreške četvrtoga ispitivača pri mjerenju možda je u položaju vrška mjernog instrumenta na zubu, što se moglo izbjeći korištenjem držača za pozicioniranje. Naime, u nekim istraživanjima spominje se držač za pravilno smještanje vrška uređaja malog promjera VITA Easyshade® Advance 4,0 (3 – 5 mm) (8,23).

I na kraju, potrebna su daljnja istraživanja kako bi se ustanovilo bi li se promijenila ponovljivost ako bi postojao ve-

Discussion

In modern dentistry today it is very important to correctly assess the color of the teeth in order to produce the same color effect of the future restoration.

In our previous study we already tested the intra-device repeatability and accuracy of dental shade-matching device (VITA Easyshade® Advance 4.0) using both *in vitro* and *in vivo* models (17). The results revealed higher L* and lower a* and b* values in the *in vivo* than the *in vitro* model, with mean differences of 3.51 and 1.25 delta E units, respectively (p<.001). 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, and the accuracy of the device tested was 93.75% (17).

Before starting color measurements, it is important not only to test the device but to test the potential independent observers to see if two or more of them watching the same events agree on what they observe. In that way, if an adequate level of inter-observer reliability is obtained, each of the observers can observe independently, perhaps at different times and/or in different locations, and their observations can be combined into one data set for analysis.

In the present study, the null hypothesis was that the color assessment tested shows no difference between four observers using the same dental shade-matching device. Although some small differences existed, our results revealed no statistically significant differences in color measurement of four observers in all the measured values (p>0.05) (Figure 3), delta E values ranged from 3.018 to 5.234 (p>0.05) (Figure 4) and observers' ICCs were very high (Table 1). Therefore, the hypothesis was confirmed.

In Lab measurements the values for all four observers were consistent, but delta E values showed wider ranges - exceeded the 50% of perceptibility threshold for a clinical mismatch in the *in vivo* model (2.6 E units) but still remained below the 50% acceptability level of 5.5 E units (8,18-21). The highest delta E value was found in the fourth observer (5.234) which almost reached the upper acceptability level and his ICC for L values was the lowest (65%) and therefore we have decided to exclude him from the further measurements (Figure 4, Table 1). Since all four observers in this study were trained and well experienced in color measurements with the tested device and we achieved the standardized conditions and illumination, this finding may be attributed to the tooth variance in surface morphology and the observer's selection of device tip position in the middle third of each tooth.

It has already been reported that there were some differences in the inter-observer reliability dependent on the type of the teeth. Lasserre et al. showed more regular inter-observer measurements on canines than those made on central incisors explaining it with more errors in measurements on the incisors mostly because of their high translucency (22). In the present study we only measured the color of the central incisors and the sample size was small (only 6 shades) and therefore it is difficult to compare the results.

The second explanation for the errors observed in the fourth observer is the device tip position that could have been

ći broj ispitivača s različitim razinama u iskustvu određivanja boje zuba, veći uzorak i više grupa zuba različitih nijansi.

Zaključak

Rezultati mjerenja pokazali su prihvatljivu pouzdanost mjerenja ispitivača uređajem za određivanje boje zuba VITA Easyshade® Advance 4,0. Razlike u srednjim vrijednostima boje iznosile su od 3,018 do 5,234, što je još uvijek u granicama kliničke prihvatljivosti. Za pravilno određivanje boje zuba, osim digitalne tehnologije, potrebni su i iskusni ispitivači.

Sukob interesa

Nije bilo sukoba interesa

avoided using the positioning jig. In some studies, the authors mentioned positioning the jig to accurately reposition the measuring unit for each shade measurement due to the smaller diameter of VITA Easyshade® Advance 4.0 (3-5 mm) (8,23).

Further research should be performed to determine whether a higher number of observers with different levels of experience in color measurement, participating subjects and groups of teeth with different shades would change the repeatability. The positioning jig is highly recommended, too.

Conclusions

The inter-examiner reliability of measurements using VITA Easyshade® Advance 4.0 shade-matching device was acceptable. The mean color differences ranged from 3.018 to 5.234, which was within the clinical acceptability level. Apart from the digital equipment, a well-trained observer is needed in order to achieve accurate dental color measurement.

Conflict of interest

None declared

Abstract

Objectives: The aim of this study was to evaluate the inter-observer reliability of dental shade-matching device using an *in vivo* model. **Materials and methods:** Four observers who were well trained in color assessment and handling of the dental shade-matching device determined teeth color and CIE-Lab values on maxillary right central incisors in 10 patients with completely healthy and intact dentitions. VITA Easyshade® Advance 4.0 shade-matching device was utilized to measure the central region of the labial surface of all investigated teeth, twice by each observer. The inter-observer reliability of the measurements was observed and deviations between Lab and E values between the observers were calculated. Intraclass correlation coefficients (ICCs) were used to analyze inter-observer reliability. **Results:** One-way ANOVA showed no statistically significant differences in color measurement of four observers in all the measured values ($p>0.05$). Delta E values ranged from 3.018 to 5.234. Although some small differences existed, statistically significant differences between the observers were not found ($p>0.05$). Inter-observer ICCs were very high for all observers (from 0.651 to 0.992). **Conclusion:** Inter-examiner reliability of measurements using VITA Easyshade® Advance 4.0 shade-matching device was acceptable. Apart from the digital equipment, a well trained observer seems to be crucial in order to achieve correct dental color measurement.

Received: November 17, 2015
Accepted: March 1, 2016

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Ključne riječi
Tooth; Color; Optical Devices

References

1. Tin-Oo MM, Saddki N, Hassan N. Factors influencing patient satisfaction with dental appearance and treatments they desire to improve aesthetics. BMC Oral Health. 2011 Feb 23;11:6.
2. Zlatarić DK, Celebić A. Factors related to patients' general satisfaction with removable partial dentures: a stepwise multiple regression analysis. Int J Prosthodont. 2008 Jan-Feb;21(1):86-8.
3. Kristek Zorić E, Žagar M, Knezović Zlatarić D. Influence of Gender on the Patient's Assessment of Restorations on the Upper Anterior Teeth. Acta Stomatol Croat. 2014;48(1):33-41.
4. Albashaireh ZS, Alhusein AA, Marashdeh MM. Clinical assessments and patient evaluations of the esthetic quality of maxillary anterior restorations. Int J Prosthodont. 2009 Jan-Feb;22(1):65-71.
5. Samorodnitzky-Naveh GR, Grossman Y, Bachner YG, Levin L. Patients' self-perception of tooth shade in relation to professionally objective evaluation. Quintessence Int. 2010 May;41(5):e80-3.
6. Paul S, Peter A, Pietrobon N, Hämmerle CH. Visual and spectrophotometric shade analysis of human teeth. J Dent Res. 2002 Aug;81(8):578-82.
7. Carsten DL. Successful shade matching--what does it take? Compend Contin Educ Dent. 2003 Mar;24(3):175-8.
8. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. J Dent. 2010;38 Suppl 2:e2-16.
9. Okubo SR, Kanawati A, Richards MW, Childress S. Evaluation of visual and instrument shade matching. J Prosthet Dent. 1998 Dec;80(6):642-8.
10. Paul SJ, Peter A, Rodoni L, Pietrobon N. Conventional visual vs spectrophotometric shade taking for porcelain-fused-to-metal crowns: a clinical comparison. Int J Periodontics Restorative Dent. 2004 Jun;24(3):222-31.
11. Kristiansen J, Sakai M, Da Silva JD, Gil M, Ishikawa-Nagai S. Assessment of a prototype computer colour matching system to reproduce natural tooth colour on ceramic restorations. J Dent. 2011 Dec;39 Suppl 3:e45-51.
12. Lehmann KM, Devigus A, Igiel C, Wentaschek S, Azar MS, Scheller H. Repeatability of color-measuring devices. Eur J Esthet Dent. 2011 Winter;6(4):428-35.
13. Khurana R, Tredwin CJ, Weisbloom M, Moles DR. A clinical evaluation of the individual repeatability of three commercially available colour measuring devices. Br Dent J. 2007 Dec 22;203(12):675-80.
14. Kielbassa AM, Beheim-Schwarzbach NJ, Neumann K, Nat R, Zantner C. In vitro comparison of visual and computer-aided pre- and post-tooth shade determination using various home bleaching procedures. J Prosthet Dent. 2009 Feb;101(2):92-100.
15. Judeh A, Al-Wahadni A. A comparison between conventional visual and spectrophotometric methods for shade selection. Quintessence Int. 2009 Oct;40(9):e69-79.

16. Fondriest J. Shade matching in restorative dentistry: the science and strategies. Int J Periodontics Restorative Dent. 2003 Oct;23(5):467-79.
17. Knezović Zlatarić D, Illeš D, Alajbeg IŽ, Žagar M. In vivo and in vitro evaluations of repeatability and accuracy of VITA Easyshade® Advance 4.0 dental shade-matching device. Acta Stomatol Croat 2015; in press.
18. Meireles SS, Demarco FF, dos Santos Ida S, Dumith Sde C, Bona AD. Validation and reliability of visual assessment with a shade guide for tooth-color classification. Oper Dent. 2008 Mar-Apr;33(2):121-6.
19. Kuehni RG, Marcus RT. An experiment in visual scaling of small color differences. Color Research and Application. 1979;4:83-91.
20. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. Dent Mater. 1987 Oct;3(5):246-51.
21. Ragain JC, Johnston WM. Color acceptance of direct dental restorative materials by human observers. Color Research and Application. 2000;25:278-85.
22. Lasserre JF, Pop-Ciutrila IS, Colosi HA. A comparison between a new visual method of colour matching by intraoral camera and conventional visual and spectrometric methods. J Dent. 2011 Dec;39 Suppl 3:e29-36.
23. Kim-Pusateri S, Brewer JD, Dunford RG, Wee AG. In vitro model to evaluate reliability and accuracy of a dental shade-matching instrument. J Prosthet Dent. 2007 Nov;98(5):353-8.