Gender-Dependent Quality of Shade Matching of Dental Professionals and Students

Sposobnost procjene boje stručnjaka iz različitih stomatoloških profesionalnih skupina i studenata dentalne medicine ovisno o spolu

Abstract

Objectives: The purpose of this study was to evaluate shade matching ability of dental professionals and students using the VITA 3D-Master shade guide. Materials and methods: A hundred and twenty participants have been assigned to one of four groups as follows: specialists in prosthodontics (SPs), residents in prosthodontics (RPs), dental technicians (DTs) and dental students (DSs). The Toothguide Training Box (TTB) was used to test the participants' shade-matching ability based on using 3 exercises and a final test. The mistakes were recorded during the exercises and mistake ratios (MR) were calculated. Time, scores, and color difference values (ΔE) were recorded and calculated. The one-way ANOVA was used to analyze the differences, and multiple regression analyses were used to evaluate the relationship in mean MRs, time, score and ΔE values between the groups. Results: Male participants needed significantly greater amount of time than females to complete the final test (P<0.05). Male SPs achieved a significantly lower percentage of mistake ratios in second exercise than RPs (P<0.05), needed significantly less time than DSs to complete the final test and achieved significantly higher scores than RPs (P<0.05). Female SPs assessed the highest and DSs and RPs the lowest color differences (P<0.05). The results obtained from the exercises and final tests highly affected the amount of estimated color difference in both male and female groups (by 78% and 76%, respectively). Conclusions: Within the population tested, gender of the participants showed a significant impact on quality of shade matching of dental professionals and students.

Received: May 3, 2020
Accepted: September 21, 2020

Address for correspondence
Professor Ćelić Robert, PhD
University of Zagreb
School of Dental Medicine
Department of Removable Prosthodontics
Gundulićeva 5, 10000 Zagreb, Croatia
Tel: +385 1 4802 111
celic@sfzg.hr

Key words
Tooth Color; Color Shade; Artificial Teeth; Color Perception; Shade Guide

Introduction

An accurate color of restoration is of a great importance to patients' satisfaction with esthetic dental outcome. Therefore, the shade determination is an important procedure in everyday dental practice, not only when using ceramic material, but also when using composite resins.

The visual analysis of natural tooth in comparison with shade guide is the fastest and least expensive method, most frequently used in dentistry (1). But color evaluation by visual comparison is a subjective method which is difficult to perform because of different environmental influences, a viewer’s interpretation and tools used (2-7).

The research carried out by Paravina et al. proved that VITA Classical A1-D4 and VITA 3D-Master shadeguides are the most frequently used shade guides (8). When it comes to teaching methods, a survey of European dental students pub-

Uvod

Točna boja protetičkoga rada značno utječe na pacijen- towo zadovoljstvo estetskim ishodom terapije. Prema to- me, procjena boje važna je postupak u svakodnevnoj klinič- koj praksi, ne samo pri uporabi keramičkih materijala nego i kompozita. Vizualna analiza prirodnih zuba uporabom klju- čev na VITA Classical A1-D4 in VITA 3D-Master (8). Kada se govori o metodama učenja, istraživanje europskih stude- nata dentalne medicine objavljeno 2011. godine pokazalo je
lished in 2011 showed that for educational purposes the most commonly used is VITA Classical A1-D4 shade guide (17-67%), followed by the VITA 3D-Master (0-47%) (9).

On the other hand, despite its widespread use, the VITA Classical A1-D4 shade guide demonstrated some difficulties with the shades that were not grouped systematically, and with the development of the 3D-Master shade guide a more systematic approach toward shade matching, with color distribution performed according to Munsell’s principles, was introduced in dentistry (10, 11).

In order to assess tooth color using the 3D Master shade guide as precise as possible and practice the procedure, the system known as the Toothguide Training Box (TTB) Mark II (Vita Zahnfabrik, Bad Sackingen, Germany) was developed to help dentists with tooth shade selection (12-14). It allows a dentist to systematically select tooth shades by determining color appearances in accordance with natural tooth color observation under the standardized artificial daylight and color temperature of 5500 K (15, 16).

The purpose of this study was to evaluate and compare the shade matching ability of four different dental occupational groups - dental technicians (DTs), residents in prosthodontics (RPs), specialists in prosthodontics (SPs) and dental students (DSs) using the VITA 3D-Master shade guide.

The first null hypothesis was that there were no gender differences in the results obtained from the exercises and the final tests using TTB in four different groups, depending on the level of their clinical experience in tooth shade evaluation. The second null hypothesis was that there were no differences in the results obtained from the exercises and final tests between four examined groups in each gender group. The third null hypothesis was that no impact of the results obtained from the exercises and final tests on the amount of estimated color difference in both gender groups was demonstrated.

Material and methods

The project of this study was approved by the Ethics Committee of the School of Dental Medicine, University of Zagreb, Croatia.

Sample size and exclusion criteria

The sample consisted of 120 participants, 30 in each of four investigated groups – DTs, RPs, SPs and DSs. A total sample size and distribution, as well as exclusion criteria and the number of participants excluded from the study have already been described in our previous paper (17).

TTB

For the study, the TTB was used. The data concerning the protocol of the TTB use has also been described in our previous paper (17).

The participants in this study had to undergo the following three structured exercises: selecting lightness, chroma and hue, respectively. After that they had to undertake the final test in which they assessed lightness, chroma and hue for each of 15 tested teeth.

da se u edukacijske svrhe najčešće odabire ključ za boju VI-
TA Classical A1-D4 (17 – 67 %), a zatim VITA 3D-Master (0 – 47 %) (9).

Istaknimo da, unatoč širokoj upotrebi, ključ za boju VI-
TA Classical A1-D4 pokazuje određene poteškoće s primjer-
cima boja koje nisu sustavno grupirane. Tek razvojem ključa za boju 3D-Master postiže se sustavni pristup procjeni boje s raspodijelom boje prema Munsellovim načelima u stomato-
logiji (10, 11).

Kako bi procjena boje zuba upotrebom ključa za boju 3D-Master bila što preciznija, razvijen je sustav Toothguide Training Box (TTB) Mark II (Vita Zahnfabrik, Bad Sackingen, Njemačka) koji doktorima dentalne medicine pomaže u uvježavanju postupka (12 – 14). Sustav omogućuje liječ
niku da sistematski odabere boju zuba određivanjem izgleda boje u skladu s promatranjem prirodne boje zuba pod standardiziranim dnevnim svjetlom i temperaturom boje od 5500 K (15, 16).

Cilj ove studije bio je ispitati i usporediti sposobnost procjene boje četiriju različitih stomatoloških profesionalnih skupina – zubnih tehničara (DT), specijalizanata stomato-
loške protetike (RP), specijalista stomatološke protetike (SP) i studenata dentalne medicine (DS) korištenjem ključa za boj
ju 3D-Master.

Prva nulta hipoteza bila je da ne postoje spolne razlike u rezultatima dobivenima tijekom vježbi i u završnom testu na TTB uređaju u četirima različitim skupinama, ovisno o razini njihova kliničkog iskustva u procjeni boje zuba. Druga nulta hipoteza glasila je da nema razlike u rezultatima dobivenima tijekom vježbi i u završnim testovima između četiriju ispiti-
vanih skupina u svakoj skupini spola. Treća nulta hipoteza bi-
la je da nema utjecaja rezultata dobivenih u vježbama i završ
nim testovima na iznos procijenjene razlike u boji u objema
spolnim skupinama.

Materijal i postupci

Projekt ove studije odobrilo je Etičko povjerenstvo Sto
matološkog fakulteta Sveučilišta u Zagrebu, Hrvatska.

Veličina uzorka i kriteriji za isključivanje iz istraživanja

Uzorak se sastojao od 120 ispitanika, po 30 u svakoj od četiriju ispitivanih skupina – DT-i, RP-i, SP-i i DS-i. Uzupni
uzorak i raspodjela, zatim kriteriji za isključivanje te broj ispi-
tanika isključenih iz studije, već su objašnjeni u našem prethodnom članku (17).

TTB

U ovoj je studiji korišten TTB uređaj. Svi podatci o pro-
tokolu upotrebe TTB uređaja također su bili objašnjeni u na-
šem članku (17).

Ispitivači u ovoj studiji bili su podvrgnuti trima struk-
turiranim vježbama u kojima su procjenjivali svjetlina, zasi-
ćenost i nijansu boje. Nakon toga su u završnom testu pro-
cjenjivali svjetlina, zasićenost i nijansu boje za svaki od 15 testiranih zuba.
Mistake ratio (MR)

The number of true answers from all three exercises of each participant was collected and the accuracy expressed as the mistake ratio of correct and total number of tries (MR 1, MR 2, and MR 3).

Time (t/s)

The time required to finish the final test was recorded in seconds in all four examined study groups.

Score

At the end of the final test each participant received a score with maximum of 1000 points.

Mean ΔE

The calculation of color difference between the task and selected colors has also been described in our previous paper (17). In calculation, the accurate answers were recorded as ΔE=0.

Statistical analysis

The received data were entered into Excel database. Subsequently, they were statistically evaluated and introduced into statistical program SPSS 19.0 (SPSS, Chicago, IL, USA).

The Student’s t test was used to compare gender differences in mean MR1, MR2, MR3, time, score and ΔE.

The one-way ANOVA was used in each gender group to determine whether there were any differences in mean MR1, MR2, MR3, time, score and ΔE values between four different examined groups, and the Bonferroni corrected post hoc tests (paired t-tests) were used to explore the differences within the groups. The differences were considered statistically significant with P<0.05.

Multiple regression analyses were used to evaluate the relationship of mean MR1, MR2, MR3, the time and score and mean ΔE values in both gender groups.

Results

126 subjects participated in our study, but only 120 were included in the study (95%). Six participants were excluded because they had previous knowledge and shade selection experience with 3D Master shade guide (2 RPs and 4 SPs), and the evaluation of the Ishihara test did not reveal color vision deficiency in any participants.

All measured variables in this study were tested for differences by gender. The results revealed significantly higher values for time needed to complete the final test in men than in women, and therefore the data in further statistical analysis were split by gender (t=2.2; df=118; P=0.03) (Figure 1).

The mistake ratios (MR) of four occupational groups by gender are shown in Figure 2. Male SPs achieved significantly higher scores than RPs (F=2.9; df=3; P=0.04) (Figures 1 and 3). In women, the SPs group assessed the mistake ratio of correct and total number of tries (MR 1, MR 2, and MR 3).

Vrijeme (t/s)

Vrijeme potrebno da se obavi završni test bilježilo se u sekundama u svim četirima ispitivanim skupinama istraživanja.

Za svakog ispitanika zabilježen je broj točnih odgovora iz svih triju vježbi te je točnost prikazana kao omjer pogreške točnih i ukupnog broja pokušaja (OP1, OP2, OP3).

Vrijeme potrebno da se obavi završni test bilježilo se u sekundama u svim četirima ispitivanim skupinama istraživanja.

Results

U ovom istraživanju ukupno je sudjelovalo 126 ispitanika, a njih 120 na kraju je bilo uključeno u studiju (95%). Šest ispitanika isključeno je jer su izjavili da ne znaju sustav i izbore za ispitivanje, a njih 120 na kraju je bilo uključeno u studiju (95%).

U ovom istraživanju ukupno je sudjelovalo 126 ispitanika, a njih 120 na kraju je bilo uključeno u studiju (95%). Šest ispitanika isključeno je jer su izjavili da ne znaju sustav i izbor za ispitivanje, a njih 120 na kraju je bilo uključeno u studiju (95%).

U ovom istraživanju ukupno je sudjelovalo 126 ispitanika, a njih 120 na kraju je bilo uključeno u studiju (95%). Šest ispitanika isključeno je jer su izjavili da ne znaju sustav i izbor za ispitivanje, a njih 120 na kraju je bilo uključeno u studiju (95%).
Figure 1 Values for time in seconds (s) needed to complete the final test of four occupational groups by gender.
Slika 1. vrijednosti vremena u sekundama (s) potrebnog za završetak završnog testa u četiri ispitaninskim skupinama prema spolu

Figure 2 The mistake ratios (MR - %) of four occupational groups by gender.
Slika 2. omjeri pogreške (OP - %) u četiri ispitaninskim skupinama prema spolu

Figure 3 The final test scores of four occupational groups by gender.
Slika 3. rezultati završnog testa u četiri ispitaninskim skupinama prema spolu

Figure 4 Calculated color differences (ΔE) of four occupational groups by gender.
Slika 4. izračunata razlika u boji (ΔE) u četiri ispitaninskim skupinama prema spolu

Table 1 Multiple regression analysis of the association between results obtained from three exercises and final tests and color differences (ΔE) in two gender groups
Tablica 1. Multipla regresijska analiza utjecaja rezultata triju vježbi i završnih testova na razliku u boji (ΔE) u muškim i ženskim ispitanicama

| R | R² | P | SE |
|---|---|---|---|
| Men • Muškarci | Women • Žene | Men • Muškarci | Women • Žene | Men • Muškarci | Women • Žene |
| ΔE | 0.89 | 0.90 | 0.78 | 0.80 | >0.05 | >0.05 |
| | 0.49 | 0.43 |

R – correlation coefficient • koeficijent korelacije; R² – coefficient of determination • koeficijent determinacije; P – significance • značajnost; SE – standard error • standardna pogreška

the highest and DSs and RPs the lowest color differences (ΔE) (F=3.5; df=3; P<0.02) (Figure 4).

In a multiple regression analysis, the combination of the results obtained from three exercises and final tests in men explained the variability of ΔE by 78% (P<0.05) (Table 1). In women, the combination of the same independent variables explained the variability of ΔE by 80% (P<0.05) (Table 1).

Discussion

The purpose of this study was to evaluate and compare the shade matching ability of four different dental occupational groups - dental technicians (DTs), residents in prosthodontics (RPs), specialists in prosthodontics (SPs) and students (SPs). The study aimed to determine if there were significant differences in the ability to match shades among these groups. The results showed that men had a higher ability to match shades compared to women.

Rasprava

Svrha ovog istraživanja bila je ispitati i usporediti sposobnost procjene boje stručnjaka iz četiri različitih stomatoloških profesionalnih skupina – dentalnih tehničara (DT), specijalizanata stomatološke protekte (RP), specijalista sto-
Sposobnost procjene boje
udiljak i sur.

and dental students (DSs) using the VITA 3D-Master shade guide.

The first null hypothesis that there will be no gender differences in the results obtained from the exercises and the final test using TTB in four examined groups, depending on their level of clinical experience in tooth shade assessment was rejected. The results of our study showed a statistically significant difference in time needed to finish the final test by gender (t=2.2; df=118; P<0.03) (Figure 1). It seemed that men needed more time than women, 17.4 minutes, and 16.1 minutes, respectively. These results are in accordance with Pohlen et al. study where they found gender to play an important role in shade matching, with female groups of participants to select lightness and chroma better compared to their male counterparts (18).

In male group in this study, SPs were the fastest in color matching and achieved lowest mistake ratios in second exercise and male DSs were the slowest in color matching with highest mistake ratios in the same exercise (P<0.05). At the same time, male SPs achieved highest scores and male RPs the lowest in the final test (P<0.05). Ortolan et al. obtained the same results, with clinicians performing the shade tab matching faster than students (19). The reason for that may lie in the fact that the specialists in prosthodontics assess the color of the teeth using different shade guides on their everyday basis compared to the students who are less experienced in this field.

According to the abovementioned results, the second null hypothesis that there will be no differences in the results obtained from the exercises and final tests between four examined groups in each gender group was also rejected. In this study, the participants were asked to undergo three exercises where they had to correctly select lightness, lightness and chroma together and, subsequently, lightness, chroma and hue of the tested teeth together, respectively. After that, the participants had to undertake the final test assessing all abovementioned color characteristics for 15 tested teeth. Although a significant difference in MR2 was found between male SPs and RP, MRs reached the highest values for both genders (around 50% of mistaken selections) in the third exercise where they were obliged to assess all three color parameters together (Figure 2). It seems that this protocol was found to be the most complicated.

The results of the research of Simmazisik et al. showed that general dentists made a larger number of mistakes in lightness parameter, and dental technicians students in hue parameter of the color (20). In our study, male D'Ts made a larger number of mistakes in lightness parameter (P<0.05), and male RPs made a larger number of mistakes in lightness and chroma and lightness, chroma and hue exercises (P<0.05), while the female group was more uniform in assessment (P>0.05; Figure 2). In their study, Haddad et al. were unable to determine the influence of experience on shade matching. Conversely, Capa et al., as well as Ragain et al., found professional experience to be associated positively with the outcome of matching the shade (21-23).

With regard to the final test scores and ∆E values in our study, no significant differences were found between occu-
pational groups in men, and SPs and DSs groups obtained higher scores (919 and 899) and lower ΔE values (1.75 and 1.95) than RSs and DTs (873 and 893, 2.67 and 2.52, respectively) (P>0.05; Figures 3 and 4). This result is in accordance with the results of the research conducted by Sinmazisik et al (20).

At the same time, however, the results were completely different in the female group in our study. The SPs obtained the lowest scores and the highest ΔE values and the RP's vice versa, and this difference was found to be significant (F=3.5; df=3; P=0.02) (Figures 3 and 4). This result was surprising, but if we look at the rest of the results and compare these female occupational groups, we will see that female SPs needed less time (15.2 min) to accomplish the entire task than female RPs (18.1 min), and they made a larger number of mistakes in the third exercise when matching lightness, chroma and hue together, which turned out to be the most difficult task (Figures 1-4). It seems that two minutes longer assessment was the most crucial for female occupational groups.

The third null hypothesis was that no impact of the results obtained from the exercises and final tests on the amount of estimated color difference in both gender groups will be demonstrated. But this was rejected because the results of multiple regression analysis revealed that there was a great impact of the variables observed in this study on the variability of ΔE. In men, it amounted to 78%, and in women 80% (P>0.05) (Table 1). It needs to be emphasized that the respondents who have previously contributed to comparable research or have been practicing color assessment, or those who had some previous shade selection knowledge or training on using the 3D Master shade guide, were excluded from the study. Therefore, the participants included in this study were dental occupational staff who accomplished this type of task for the first time with no preliminary lectures. They have undergone three training exercises where they have learnt how to assess color arranged by lightness, chroma and hue, step-by-step, and, after that, they did their final test. The results of our study proved that this type of training with no previous lectures strongly influenced the final result in both male and female groups (ΔE) (P>0.05) (Table 1). Many experts in this field have already emphasized the need for training in color science and found that lessons on color selection, along with training and experience can improve the color matching ability of dental professionals (14, 20-24).

At the same time, various articles claim that previous experience does not improve nor has a minimal impact on the ability of color selection (18, 21, 25).

In this study, we wanted to investigate not only the results of the final test, but also the results of three exercises preceding the final test in order to explore their impact on the amount of estimated color difference. In our further study, we want to explore in detail which VITA 3D-Master shades were most often assessed accurately. Additionally, we would like to investigate into the VITA 3D-Master shades that were most often assessed incorrectly in different dental occupational groups.
Conclusions

In this study, men needed more time to complete the final test. Male SPs made a smaller number of mistakes in second exercise, needed significantly less time to complete the final test and achieved significantly higher scores (P<0.05). Female SPs assessed highest, and DSs and RPs the lowest color differences (P<0.05). When assessing lightness, chroma and hue simultaneously, the participants made a larger number of mistakes. Male SPs and DTs were the most successful in final shade matching, and female DSs were more successful than female SPs. The results of exercises and final tests influenced the amount of color difference in both men and women.

Conflict of interest

None declared

Contribution to the paper:

Ž. D. - writing the article (Introduction/Purpose of the study, Material and methods; Results, Discussion with Conclusions); sample collection (dental students, dental prosthetics specialists, dental technicians); implementation of the experimental part of the study, review of the scientific literature; H. P. - sample collection (dental technicians; dental prosthetics specialists); R. Ć. - writing the article (Introduction/Purpose of the study, Material and methods; Results, Discussion with Conclusions - control of the whole writing process), sample collection (dental students, dental prosthetics specialists, dental prosthetic specialists, dental technicians); review of the scientific literature.

Zaključci

Muškarci su u ovom istraživanju potrošili više vremena da dovrsi završni test. Specijalisti stomatološke protetike (SP) imali su manje pogrešaka u drugoj vježbi, trebalo im je znatno manje vremena da dovrsi završni test i postigli su značajno bolje rezultate (P<0.05). Specijaliste protetike (SP) imale su najviše, a dentalne studentice (DS) i specijalizante stomatološke protetike (RP) najniže razlike u boji (P<0.05). Kada se procjenjivala svjetlina, zasićenost i nijanse boje istodobno, ispitanici su učinili više pogrešaka. Specijalisti (SP) i dentalni tehničari (DT) bili su najuspješniji u završnoj procjeni boje, a studentice dentalne medicine (DS) bile su uspješnije od specijalista stomatološke protetike (SP). Rezultati vježbi i završnih testova utjecali su na iznos razlike u boji muških i ženskih ispitanika.

Conflict of interest

None declared

Doprinos autoru

Ž. U. - pisanje članka (Uvod/Svraža istraživanja, Materijal i metoda; Rezultati, Rasprava s zaključcima); skupljanje uzorka (studenti dentalne medicine, specijalizanti stomatološke protetike, zubni tehničari); provedba eksperimentalnog dijela istraživanja, pregled znanstvene literature; H. P. - skupljanje uzorka (zubni tehničari, specijalisti stomatološke protetike); R. Ć. - pisanje članka (Uvod/Svraža istraživanja, Materijal i metoda; Rezultati, Rasprava s zaključcima – kontrola cijelog procesa pisanja), skupljanje uzorka (studenti dentalne medicine, specijalizanti stomatološke protetike, specijalisti stomatološke protetike, zubni tehničari); pregled znanstvene literature.

References

1. Van der Burgt TP, ten Bosch JJ, Borsboom PC, Kortsmit WJ. A comparison of new and conventional methods for quantification of tooth color. J Prostheth Dent. 1990 Feb;63(2):155-62.

2. 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.

3. 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.

4. Okubo SR, Kanawati A, Richards MW, Childress S. Evaluation of visual and instrument shade matching. J Prostheth Dent. 1998 Dec;80(6):642-8.
5. Carsten DL. Successful shade matching—what does it take? Compend Contin Educ Dent. 2003;24(3):175-8.
6. Clary JA, Ontiveros JC, Cron SG, Paravina RD. Influence of light source, polarization, education, and training on shade matching quality. J Prostheth Dent. 2016 Jul;116(1):91-7.
7. Gáspárík C, Tofan A, Culic B, Badea M, Dusea D. Influence of light source and clinical experience on shade matching. Clujul Med. 2014;87(1):30-3.
8. Paravina RD, O'Neill PN, Swift EJ Jr, Nathanson D, Goodacre CJ. Teaching of color in predoctoral and postdoctoral dental education in 2009. J Dent. 2010;38 Suppl 2:e34-40.
9. Dozic A, Kharbanda AK, Kameli H, Brand HS. European dental students’ opinions about visual and digital tooth colour determination systems. J Dent. 2011 Dec;39 Suppl 3:e23-8.
10. Corcodel N, Karatzogiannis E, Rammelsberg P, Hassel AJ. Evaluation of two different approaches to learning shade matching in dentistry. Acta Odontol Scand. 2012 Jan;70(1):83-8.
11. Hammad IA. Intra-rater repeatability of shade selections with two shade guides. J Prostheth Dent. 2003 Jan;89(1):50-3.
12. Draghici R, Preoteasa CT, Tănăcu A, Preoteasa E. Dental color assessment through TTB exercises. J Med Life. Jan-Mar 2016;9(1):61-65.
13. Olms C, Klinke T, Pirek P, Hannak WB. Randomized multi-study on the effect of training on tooth shade matching. J Dent. 2013 Dec;41(12):1259-63.
14. Llena C, Forner L, Ferrari M, Amengual J, Llambes G, Lozano E. Toothguide Training Box for dental color choice training. J Dent Educ. 2011 Mar;75(3):360-4.
15. Corcodel N, Rammelsberg P, Jakstat H, Moldovan O, Schwarz S, Hassel AJ. The linear shade guide design of Vita 3D-master performs as well as the original design of the Vita 3D-master. J Oral Rehabil. 2010 Nov;37(11):860-5.
16. Borbély J, Varsáni B, Fejérdy P, Hermann P, Jakstat HA. Toothguide Trainer tests with color vision deficiency simulation monitor. J Dent. 2010;38 Suppl 2:e41-9.
17. Udiljak Ž, Illeš D, Knezović Zlatarić D, Ćelic R. Effect of Clinical Experience on the Shade Matching Accuracy in Different Dental Occupational Groups. Acta Stomatol Croat. 2018;52(2):132-139.
18. Pohlen B, Hawliina M, Šober K, Kopač I. Tooth Shade-Matching Ability Between Groups of Students with Different Color Knowledge. Int J Prosthodont. Sep-Oct 2016;29(5):487-92.
19. Ortolan SM, Persic S, Celebic A, Mehulic K. Comparison of time consumption and color matching results of different dental occupational groups. Int J Prosthodont. Sep-Oct 2013;26(5):478-86.
20. Sinmazisik G, Trakyali G, Tarcin B. Evaluating the ability of dental technician students and graduate dentists to match tooth color. J Prostheth Dent. 2014 Dec;112(6):1559-66.
21. Haddad HJ, Jakstat HA, Arnetzl G, Borbely J, Vichi A, Dumfahrt H, Renault P, Corcodel N, Pohlen B, Marada G, de Parga JA, Reshad M, Klinke TJ, Hannak WB, Paravina RD. Does gender and experience influence shade matching quality? J Dent. 2009;37 Suppl 1:e40-4.
22. Capa N, Malkondu O, Kazazoglu E, Calikkoacaglu S. Evaluating factors that affect the shade-matching ability of dentists, dental staff members and laypeople. J Am Dent Assoc. 2010 Jan;141(1):71-6.
23. Ragain JC Jr, Johnston WM. Minimum color differences for discriminating mismatch between composite and tooth color. J Esthet Restor Dent. 2001;13(1):41-8.
24. Xu MM, Xu TK, Liu F, Shi XR, Feng HL. The influence of toothguide training box on shade matching veracity. Shanghai Kou Qiang Yi Xue. 2009 Aug;18(4):432-5.
25. Della Bona A, Barrett AA, Rosa V, Pinzetta C. Visual and instrumental agreement in dental shade selection: three distinct observer populations and shade matching protocols. Dent Mater. 2009 Feb;25(2):276-81.