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*IZVORNI ZNANSTVENI RAD*



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# Effects of Different Whitening Agents on the Color and Translucency of Different Resin Composites

# *Učinci različitih sredstava za izbjeljivanje na boju i translucenciju različitih smolastih kompozitnih materijala*

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**Abstract**

**Objectives:** To examine the effects of different whitening agents on the color and translucency of different resin composites, *in vitro*. **Material and methods:** A total of 315 specimens (10.0×2.0 mm) were fabricated from two microhybrid (G-aenial anterior [G-Ant] ) and (G-aenial posterior [G-Post]) and a nano hybrid (G-aenial A'CHORD [ G-ACH]) resin composites and each group was randomly distributed into seven experimental groups (n=15) as follows; 1- control (C); 2- in-office whitening agent (IOW); 3- at-home whitening agent (AHW); 4- prefilled tray (PT); 5- whitening pen (WP); 6- whitening toothpaste (WT) and 7- whitening mouthwash (WMW). The specimens were subjected to staining except control group before application of the different whitening procedures. The color of specimens was measured after 24 h ($T_0$), after staining ($T_1$) and after whitening ($T_2$). Color change [CIEDE2000 ($ĆE_{00}$)], translucency parameter (TP) values and changes in whiteness index ($WI_D$) were calculated. Data were analyzed statistically ($p<0.05$). **Results:** No significant $WI_D$ differences were detected among the tested resin composites at $T_0$ and $T_1$ ($p>0.05$), whereas a significant difference was observed at $T_2$ ($p<0.005$). AHW and IOW produced higher color change than PT, WP, WT and WMR. Significant TP changes were found after the application of IOW and AHW in G-Ant. **Conclusion:** The effect of whitening products on the whitening index, color and translucency of resin composites are material and substrate dependent.

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## Introduction

The color, shape and surface texture of the teeth are very important in facial aesthetics and characteristics. They add a personal touch to a smile. Nowadays, patients have a strong desire for whiter teeth, which is reasonable as tooth whitening is a relatively noninvasive approach for the teeth to achieving this goal (1). Nevertheless, one must take into account the impact of tooth whitening on the visual appeal of tooth-colored restorative materials. Potential changes induced by whitening can be clinically significant to the point where they may affect the quality of dental restorations, and possibly necessitate their replacement. For whitening, a series of methods have been launched, each with their own mechanism of action. The success of whitening procedure depends on the following three factors: particular substrate discoloration that is being treated, whitening agent and method and color of the substrate. Currently available agents are usually based on peroxide gels in different concentrations for home and in-office whiten-

## Uvod

Boja, oblik i tekstura površine zuba vrlo su važni u estetici zbog karakteristika i davanja osobnog pečata osmijehu. Danas je razumna želja pacijenata za bjeljim zubima jer je njihovo izbjeljivanje razmjerno neinvazivan način da se postigne taj cilj (1). Ipak, treba uzeti u obzir utjecaj izbjeljivanja na izgled restaurativnih materijala u boji zuba. Potencijalne promjene izazvane izbjeljivanjem mogu biti klinički važne do te mjere da mogu utjecati na kvalitetu restauracija i možda zahtijevati njihovu zamjenu. Za izbjeljivanje postoji niz metoda i svaka ima svoj mehanizam djelovanja. Uspjeh postupka ovisi o trima čimbenicima: o diskoloraciji podloge koja se tretira, o sredstvu za izbjeljivanje te o načinu izbjeljivanja. Trenutačno dostupna sredstva obično se temelje na peroksidnim gelovima u različitim koncentracijama za izbjeljivanje kod kuće i u ordinaciji (2, 3), trakama za izbjeljivanje (OTC), gelovima, sredstvima za ispiranje, pastama za zube i izbjeljivačima u udlagama (4).

ing (2, 3) and over the counter (OTC) whitening strips, gels, rinses, toothpastes and tray based tooth whiteners (4).

The interaction between a whitening agent and restorative material is of great clinical importance since drastic color changes of existing restorations may compromise esthetics and patient's perception of the color change (5, 6). Therefore, it is an imperative to accurately assess the effect of whitening agents on the optic properties of restorative materials, and it needs to be clinically well estimated. Patients anticipate that whitening therapy will yield equivalent results on both restored teeth and aesthetically enhanced restorative materials. Clinically unacceptable tooth discoloration beyond the clinically acceptable limits is the fundamental reason for restoration replacements (7, 8). One of the main causes for replacing esthetic restorations due to discoloration is the consumption of dietary items by the patient, particularly staining beverages like tea or coffee (9, 10). These liquids have the potential to deposit on external surfaces of the restorations and teeth. Accordingly, they are accepted as  major cause of extrinsic stains. Furthermore, they can also affect the perceived shade of the restorations, (9, 11, 12) and as a consequence, the process to attempt and maintain good color harmony between the restorative material and restored or adjacent tooth structure is compromised.

Currently, there is a prevailing trend of whiter teeth through easy, inexpensive and effortless whitening through social media posts, TV or internet advertisements and many people randomly use these whitening agents with or without being monitored by a professional. In recent years, there have been an increase in the number of studies to evaluate the effectiveness of different whitening procedures on different restorative materials (13). However, the existing research mostly focuses on the assessment of the impact of whitening systems on the color, micro hardness, roughness, translucency and gloss of the restorative materials (14-19). To the best of the authors' knowledge, there have been no studies comparing at-home, in-office whitening and different OTC products on three different resin composites suggested to be used in anterior, posterior or both in anterior and posterior teeth. Therefore, the aim of this *in vitro* study was to evaluate the effects of six different whitening procedures on different resin composites stained with tea solution. The null hypothesis was that there would be no differences in the whiteness index, color and translucency among the tested resin composites after application of different whitening regimens.

## Materials and methods

### Material selection

Table 1 presents a list of tested materials. The resin composites tested have different indications and compositions: a micro hybrid, indicated to be used in anterior (G-aenial anterior [G-Ant], GC, Tokyo, Japan); a micro hybrid (G-aenial posterior [G-Post]), suggested to be used in posterior; GC, Tokyo, Japan) and a universal nano hybrid resin composite (G-aenial A'chord [G-ACH], GC, Tokyo, Japan) used both in anterior and posterior teeth. A2 shade was selected in all groups for standardization of the color.

Interakcija između sredstva za izbjeljivanje i restaurativnog materijala iznimno je klinički važna s obzirom na to da drastične promjene boje postojećih ispuna mogu ugroziti estetiku i pacijentovu percepciju o promjeni boje (5, 6). Zato je nužno točno klinički procijeniti učinak sredstava za izbjeljivanje na optička svojstva restaurativnih materijala. Pacijenti očekuju da će se terapijom izbjeljivanja postići jednaki rezultati i na popravljenim zubima i na restaurativnim materijalima. Klinički neprihvatljiva diskoloracija zuba iznad klinički prihvatljivih granica osnovni je razlog za zamjenu nadomjestaka (7, 8). Jedan od glavnih uzroka za zamjenu estetskih nadomjestaka zbog diskoloracije jest konzumacija namirnica, posebice pića koja ostavljaju mrlje poput čaja ili kave (7, 8). Te se tekućine mogu taložiti na vanjskim površinama nadomjestaka i zuba. Sukladno tomu, prihvaćene su kao glavni uzrok vanjskih obojenja. Nadalje, također mogu utjecati na percipiranu nijansu nadomjestaka (9 – 10) i kao posljedica toga, ugroženo je održavanje sklada između boje restaurativnog materijala i restaurirane ili susjedne strukture zuba.

Trenutačno prevladava trend izbjeljivanja zuba jednostavnim i jeftinim sredstvima koja se nabavljaju bez poteškoća putem objava na društvenim mrežama, TV-a ili internetskih reklama i mnogi ih ljudi nasumično upotrebljavaju uz nadzor stručnjaka ili bez toga nadzora (9, 11, 12). Posljednjih godina povećan je broj istraživanja za procjenu učinkovitosti različitih postupaka izbjeljivanja na različitim restaurativnim materijalima (13). No ta istraživanja uglavnom su usmjerena na procjenu utjecaja sustava za izbjeljivanje na boju, mikrotvrdoću, hrapavost, prozirnost i sjaj restaurativnih materijala (14 – 19). Koliko je poznato autorima, nije bilo istraživanja u kojima bi se uspoređivalo izbjeljivanje kod kuće ili u ordinaciji i različiti OTC proizvodi na trima različitim kompozitnim smolama za koja se predlaže da se koriste na prednjim, stražnjim ili i na prednjim i na stražnjim zubima. Stoga je cilj ovog istraživanja *in vitro* bio procijeniti učinke šest različitih postupaka izbjeljivanja na različite kompozitne smole obojene otopinom čaja. Nulta hipoteza glasila je da neće biti razlika u indeksu bjeline, boji i translucenciji između testiranih kompozitnih smola nakon primjene različitih režima izbjeljivanja.

## Materijali i metode

### Odabir materijala

U tablici 1. popis je ispitanih materijala. Testirane kompozitne smole imaju različite indikacije i sastave: mikrohibridna, indicirana za ispune na prednjim zubima (G-aenial anterior [G-Ant], GC, Tokio, Japan), mikrohibridna [G-aenial posterior (G-Post) koji se predlaže za ispune na stražnjim zubima; GC, Tokio, Japan] i univerzalna nanohibridna kompozitna smola [G-aenial A'chord (G-ACH), GC, Tokio, Japan] koja se upotrebljava i za prednje i za stražnje zube. U svim skupinama odabrana je nijansa A2 radi standardizacije boje.

**Table 1** Resin composites and whitening products used in the study
**Tablica 1.** Kompozitne smole i proizvodi za izbjeljivanje korišteni u istraživanjima

| Brand • Marka | Manufacturer • Proizvođač | Composition • Sastav |
|---|---|---|
| G-aenial anterior | GC, Tokyo, Japan | Resin matrix: CQ, UDMA, 73 wt%/64 vol%, Prepolymerized fillers (16–17 mm; silica, strontium and lanthanoid fluoride), 850 nm silica, glass, 16 nm fumed silica • Smolasta matrica: CQ, UDMA, 73 wt%/64 vol%, predpolimerizirana punila (16 –17 mm; silicij, stroncij i lantanoidni fluorid), 850 nm silicij, staklo, 16 nm silika |
| G-aenial posterior | GC, Tokyo, Japan | Resin matrix: BısEMA, CQ, UDMA, 77 wt%/65 vol%, Prepolymerized fillers (16–17 mm; silica, strontium and lanthanoid fluoride), fluoroaluminosilicate, 16 nm fumed silica • Smolasta matrica: BısEMA, CQ, UDMA, 77 wt%/65 vol%, predpolimerizirana punila (16–17 mm ; silicij, stroncij i lantanoidni fluorid), fluoroaluminosilikat, 16 nm silika |
| G-aenial A'chord (Universal resin composite) | GC, Tokyo, Japan | Resin matrix: Bis-MEPP, 82 wt% : Glass-filler (300nm barium glass) 16nm (fumed silica), Organic filler (300nm barium glass;16nm fumed sílica). • Smolasta matrica: Bis-MEPP, 82 wt%: stakleno punilo (300 nm barijevo staklo), 16 nm (pareni silicij), organsko punilo (300 nm barijevo staklo; 16 nm pareni silicij). |
| Opalescence BOOST | Ultradent Products, South Jordan, USA • SAD | 1.1% Sodium fluoride and 3% potassium nitrate, chemical activator, 40% hydrogen peroxide • 1,1 % natrijev fluorid i 3 % kalijev nitrat, kemijski aktivator, 40 % vodikov peroksid |
| Opalescence PF 10 | Ultradent Products, South Jordan, USA • SAD | 10% Carbamide peroxide , polyacrylic acid , 0.3%, sodium fluoride , 3% sodium hydroxide • 10 % karbamid-peroksid, poliakrilna kiselina, 0,3 %, natrijev fluorid, 3 % natrijev hidroksid |
| Opalescence Go (Prefilled Tray) | Ultradent Products, South Jordan, USA • SAD | 6 % Hydrogen Peroxide, sodium hydroxide, potassium nitrate, sodium fluoride • 6 % vodikov peroksid, natrijev hidroksid, kalijev nitrat, natrijev fluorid |
| Cavex Bite&White (Whitening Pen) | Cavex, Haarlem, Holland | 6% Hydrogen Peroxide, polyethylene glycol, PVP peroxide, glycerin, Peppermint oil • 6% hidrogen-peroksid, polietilen glikol, PVP peroksid, glicerin, ulje paprene metvice |
| Opalescence (Whitening Toothpaste) | Ultradent Products, South Jordan, USA • SAD | Sodium fluoride, glycerin, water (aqua), silica, sorbitol, xylitol, flavor, poloxamer, sodium lauryl sulfate, carbomer, FD&C Blue # 1 (Cl 42090), FD&C Yellow # 5 (Cl 19140), sodium benzoate, sodium hydroxide, Sparkle (CI 77019, CI 77891), sucralose, xanthan gum. • Natrijev fluorid, glicerin, voda (aqua), silicij, sorbitol, ksilitol, aroma, poloksamer, natrijev lauril-sulfat, karbomer, FD&C plava # 1 (Cl 42090), FD&C žuta # 5 (Cl 19140), natrijev benzoat, natrijev hidroksid, sjajilo (CI 77019, CI 77891), sukraloza, ksantanska guma. |
| Listerine Healty White (Whitening Mouth Rinse) | Johnson & Johnson, New Jersey, USA • SAD | Sodium fluoride 0.02% (0.01% w/v fluoride ion) (Anticavity). Inactive Ingredients:Water, alcohol (8%), hydrogen peroxide, poloxamer 407, sodium saccharin, sucralose, menthol, phosphoric acid, disodium phosphate, flavor. • Natrijev fluorid 0,02 % (0,01% w/v fluoridnog iona). Neaktivni sastojci: voda, alkohol (8 %), vodikov peroksid, poloksamer 407, natrijev saharin, sukraloza, mentol, fosforna kiselina, dinatrijev fosfat, aroma. |

The selection criteria for the whitening procedures were: different compositions of the materials; including in-office whitening (40% Hydrogen Peroxide [HP], Opalescence Boost, Ultradent, South Jordan, USA [IOW]); at-home whitening (Opalescence,10% Carbamide Peroxide [CP], Ultradent, South Jordan, USA [AHW]) and four different OTC products, namely a prefilled tray (Opalescence Go, 6%HP Ultradent, South Jordan, USA [PT]); a whitening pen (6% HP, Cavex Bite&White, Cavex, Haarlem, Nederland [WP]); a whitening toothpaste (Opalescence, Ultradent, South Jordan, USA [WT]) and a whitening mouth rinse (2% HP, Listerine Advanced White, Johnson & Johnson, New Jersey, USA [WMR]).

## Sample size calculation

A preliminary experiment was made to determine sample size. The α-value was 0.05, a mean standard deviation was 0.11, and a power was 0.95. The analysis revealed at least 11 specimens for each group to obtain significant differences among the groups. Thus, a total of 15 specimens per group were prepared.

Kriteriji odabira za postupke izbjeljivanja bili su različiti sastavi materijala. Uključeno je izbjeljivanje u ordinaciji [40-postotni vodikov peroksid (HP), Opalescence Boost, Ultradent, South Jordan, SAD (IOW)], izbjeljivanje kod kuće [Opalescence, 10-postotni karbamidni peroksid (CP), Ultradent, Južni Jordan, SAD (AHW)] i četiri različita OTC proizvoda, tj. unaprijed napunjena udlaga [Opalescence Go, 6-postotni HP Ultradent, Južni Jordan, SAD (PT)], olovka za izbjeljivanje [6-postotni HP, Cavex Bite &White, Cavex, Haarlem, Nizozemska (WP)], zubna pasta za izbjeljivanje [Opalescence, Ultradent, South Jordan, SAD (WT)] i sredstvo za ispiranje usta za izbjeljivanje [2-postotni HP, Listerine Advanced White, Johnson & Johnson, New Jersey, SAD ˙(WMR)].

## Izračun veličine uzorka

Proveden je preliminarni eksperiment kako bi se odredila veličina uzorka. S obzirom na α-vrijednost od 0,05, srednju standardnu devijaciju od 0,11 i snagu od 0,95, analiza je pokazala da je potrebno najmanje 11 uzoraka za svaku skupinu da bi se među njima dobile značajne razlike. Tako je pripremljeno ukupno 15 uzoraka po skupini.

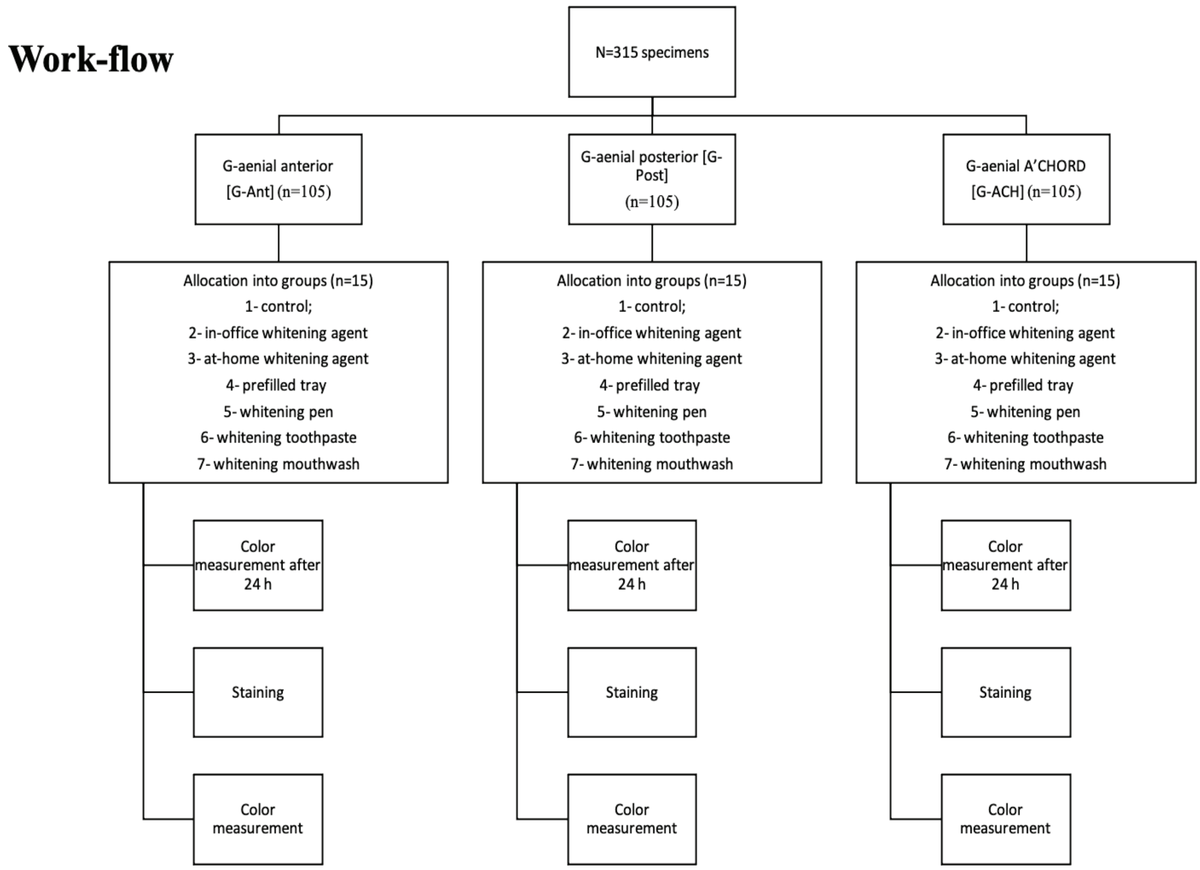


**Figure 1** Work-flow of the study
**Slika 1.** Tijek istraživanja

### Specimen preparation

A total of three hundred and fifteen disc-shaped specimens measuring 10.0 mm in diameter ×2.0 mm in height were fabricated from resin composites (n=105) by placing the materials in stainless-steel molds. The molds with the Mylar strips and microscopic glass slides on top and bottom sides were filled with respective resin composites, and a finger which was pressed gently to extrude the excess material. Subsequently, each specimen was 20 s light irradiated on top and bottom surfaces of the specimens by a light emitting diode (LED) (Elipar Freelight 2, 3M ESPE, St. Paul, USA/1000 mW/cm$^2$). The device underwent regular inspections to verify irradiance values using a digital radiometer (Bluephase Meter II, Ivoclar, Amherst, USA). Following the removal of specimens from the molds, they were placed in distilled water (37°C) for 24 h. Subsequently, the specimens were finished and polished using a sequence of Sof-Lex discs of Sof-Lex discs (3M/ ESPE, St. Paul, USA). The discs were replaced after every 2 specimens, following a decreasing order, with intermittent movements.

### Staining of the resin composite specimens

A concentrated black tea solution was prepared by infusion of 16g of tea (10-sachet) in 500 mL of water. When the solutions reached 37°C, the specimens were immersed in the solutions (20). The immersion protocol for the staining was as follows: a 18- hour immersion in the tea infusion, then a 6-

### Priprema uzoraka

Ukupno tristo petnaest uzoraka u obliku pločica, promjera 10,0 mm × 2,0 mm debljine, proizvedeno je od kompozitnih smola (n = 105) stavljanjem materijala u kalupe od nehrđajućeg čelika. Kalupi s trakama Mylar i mikroskopskim stakalcima na gornjoj i donjoj strani napunjeni su odgovarajućim kompozitnim smolama i nježno pritisnuti prstom da se istisne višak materijala. Zatim je svaki uzorak osvijetljen 20 sekunda na gornjoj i donjoj površini uzoraka diodonom svjetiljkom (LED) (Elipar Freelight 2, 3M ESPE, St. Paul, SAD/1000 mW/cm$^2$). Uređaj je podvrgnut redovitoj inspekciji za provjeru vrijednosti ozračenja s pomoću digitalnog radiometra (Bluephase Meter II, Ivoclar, Amherst, SAD). Nakon vađenja uzoraka iz kalupa, stavljeni su 24 sata u destiliranu vodu (37 °C). Nakon toga uzorci su dorađeni i polirani korištenjem niza Sof-Lex diskova (3M/ESPE, St. Paul, SAD). Diskovi su zamijenjeni nakon svaka dva uzorka, prema silaznom redoslijedu, isprekidanim pokretima.

### Obojenje uzoraka kompozitne smole

Koncentrirana otopina crnog čaja pripremljena je infuzijom 16 g čaja (10 vrećica) u 500 mL vode. Kada su otopine dosegnule 37 °C, uzorci su uronjeni u otopine (17). Protokol uranjanja za bojenje bio je sljedeći: 18-satno uranjanje u čajnu infuziju, zatim 6-satno sušenje na sobnoj temperatuhour drying at room temperature. The specimens were subjected to 4 complete cycles of immersion (15).

### Whitening protocols

Instructions of the manufacturers of each whitening agents were strictly followed. The test groups and application procedures were as follows:

G1- (C) (n: 15): The specimens of this group were stored in distilled water refreshed daily at 37°C for 14 days.

G2- (IOW) (In-Office whitening agent, 40% HP) (n:15): The whitening gel was applied in a thin and even layer of about 1.5 mm on the specimen surfaces as recommended by the manufacturer, and it remained 20 min in 37°C humidity. Three consecutive applications were performed, which resulted in 60 min of application time. After each session, the whitening gel was washed for 1 min and the specimens were transferred into distilled water.

G3-(AHW) (at- home whitening agent, 10% CP) (n:15): The whitening gel was applied with a brush onto the specimens' surfaces approximately 1 mm thick for 8 hours a day and kept in humid atmosphere at 37° C for 14 consecutive days according to the recommendations of the manufacturer. At the end of each whitening procedure, the whitening gel was cleaned off and the specimens were thoroughly rinsed and then transferred into distilled water.

G4- (PT) (prefilled tray) (n: 15): After the prefilled whitening tray was taken out from its packaging, the colored outer tray was removed leaving the white inner tray. This layer was cut according to the size of the specimen and the specimen surface was covered with the whitening strip for 30 min daily for 14 days. After each whitening session, the specimens were thoroughly rinsed, and then kept in distilled water.

G5- (WP) (whitening pen) (n:15): After the cap of the whitening pen was taken off, the pen button was turned until a small droplet of whitening gel appeared on the tip brush and a thin layer of gel was applied onto the specimen surface for 30 min a day for 14 days. At the end of each treatment, specimens were thoroughly rinsed and then transferred into distilled water.

G6- (WT) (Whitening Toothpaste) (n:15): Specimens in this group were brushed with the whitening toothpaste prepared with distilled water at a 1:3 (w/v) proportion (21) using a soft electric toothbrush (Triumph 5000 D34; Oral B, Braun GmbH, Kronberg Germany) in daily mouth cleaning mode for 2 min twice daily for 14 days (22). Following brushing with whitening toothpaste, the specimens were thoroughly rinsed and then transferred into distilled water.

G7- (WMR) (whitening mouth rinse) (n: 15): The specimens in this group were immersed in whitening mouth rinse for 2 min twice a day for 14 days. They were then thoroughly rinsed and then stored in distilled water.

### Color measurement of the resin composite specimens

Color measurements were made under D65 illumination light by a spectrophotometer (CM-700d, Konica Minolta, Tokyo, Japan) equipped with software (Spectra Magic NX, Konica Minolta). The values were expressed as CIE L*a*b*

ri. Uzorci su podvrgnuti četirima potpunim ciklusima uranjanja (15).

### Protokoli izbjeljivanja

Strogo su se poštovale upute proizvođača svakog sredstva za izbjeljivanje. Ispitne skupine i postupci primjene bili su sljedeći:

G1 - (C) (n:15): uzorci iz ove skupine pohranjeni su u destiliranoj vodi koja se 14 dana svakodnevno mijenjala na 37 °C

G2 - (IOW) (sredstvo za izbjeljivanje u ordinaciji, 40 % HP) (n:15): gel za izbjeljivanje nanesen je u tankom i ravnomjernom sloju od oko 1,5 mm na površine uzoraka prema preporuci proizvođača i ostao je 20 minuta pri 37 °C vlažnosti. Provedene su tri uzastopne primjene, što je rezultiralo vremenom primjene od 60 minuta. Nakon svake sesije gel za izbjeljivanje ispiran je jednu minutu, a uzorci su prebačeni u destiliranu vodu.

G3 - (AHW) (sredstvo za izbjeljivanje kod kuće, 10 % CP) (n:15): gel za izbjeljivanje nanesen je kistom na površine uzoraka debljine približno 1 mm tijekom 8 sati na dan i držan 14 uzastopnih dana u vlažnoj atmosferi na 37 °C prema preporukama proizvođača. Na kraju svakog postupka izbjeljivanja, gel za izbjeljivanje je očišćen, a uzorci su temeljito isprani i zatim prebačeni u destiliranu vodu.

G4 - (PT) (unaprijed napunjena udlaga) (n:15): nakon što je napunjena udlaga za izbjeljivanje izvađena iz pakiranja, vanjska udlaga u boji uklonjena je i ostala je bijela unutarnja udlaga. Taj je sloj izrezan prema veličini uzorka i površina uzorka prekrivena je trakom za izbjeljivanje 30 minuta na dan tijekom 14 dana. Nakon svakog izbjeljivanja uzorci su temeljito isprani, a zatim držani u destiliranoj vodi.

G5 - (WP) (olovka za izbjeljivanje) (n:15): nakon što je skinuta kapica olovke za izbjeljivanje, gumb olovke okretao se sve dok se mala kapljica gela za izbjeljivanje nije pojavila na vrhu četkice te je tanki sloj gela nanesen na površinu uzorka 30 minuta na dan tijekom 14 dana. Na kraju svakog tretmana uzorci su temeljito isprani i zatim prebačeni u destiliranu vodu.

G6 - (WT) (pasta za izbjeljivanje zuba) (n:15): uzorci u ovoj skupini četkani su pastom za izbjeljivanje zuba pripremljenom s destiliranom vodom u omjeru 1 : 3 (w/v) (18) s pomoću mekane električne četkice za zube (Triumph 5000 D34; Oral B, Braun GmbH, Kronberg Njemačka) u svakodnevnom načinu čišćenja usta dvije minute dva puta na dan tijekom 14 dana (19). Nakon pranja zuba pastom za izbjeljivanje, uzorci su temeljito isprani, a zatim preneseni u destiliranu vodu.

G7 - (WMR) (otopina za ispiranje usta s učinkom izbjeljivanja) (n:15): uzorci u ovoj skupini bili su uronjeni u otopinu za ispiranje usta s dvominutnim učinkom izbjeljivanja dva puta na dan tijekom 14 dana. Zatim su temeljito isprani i pohranjeni u destiliranoj vodi.

### Mjerenje boje uzoraka kompozitne smole

Mjerenja boja provedena su pod iluminacijskim svjetlom D65 spektrofotometrom (CM-700d, Konica Minolta, Tokio, Japan) opremljenim softverom (Spectra Magic NX, Konica Minolta). Vrijednosti su izražene u CIE L*a*b* prostoru color space. L* is lightness, from white to black (100 - 0), a* is red – green and b* is yellow – blue chromatic coordinates.

The color measurements were done in three different periods; at baseline (after 24 hours) ($T_0$), after staining ($T_1$) and after whitening ($T_2$). The analyses were performed placing the specimens against white and black backgrounds. The color measurements were performed in triplicate at the center of the top surface of each specimen and averaged.

Whitening index ($WI_D$) was calculated at $T_0$, $T_1$ and $T_2$ according to following formula (23):

$$WI_D = 0.511L^* - 2.324a^* - 1.100b^*$$

Color change ($\Delta E_{00}$) was calculated according to CIEDE2000 (24, 25).

The translucency parameter (TP) was revealed using the following equation (26, 27):

$$TP = \left[(L_B^* - L_W^*)^2 + (a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2\right]^{1/2}$$

In this formula, $L_W$, $a_W$ $b_W$ color coordinates was obtained against white background, while $L_B$ $a_B$ $b_B$ against black.(28) TP ranged between 0 - 100 and higher the TP means the increased translucency, on the contrary, lower TP values means increased opacity.(27) Translucency of specimens after 24 h (T0), after staining (T1) and after whitening (T2) was calculated.

The difference in TP (ΔTP) was calculated using the following formula (28):

$\Delta TP_1$ = TP1 – TP0 (staining - baseline)
$\Delta TP_2$ = TP2 – TP1 (whitening - staining)
$\Delta TP_3$ = TP2 – TP0 (whitening - baseline)

### Statistical analysis

SPSS 20.0 statistical software (Superior Performing Software Systems, Chicago, USA) was employed for analysis. For each group, mean whiteness color shade and translucency at different times of investigation was calculated with standard deviation and 95 % confidence interval. The Kolmogorov-Smirnov test showed that the data distribution was inhomogeneous. Therefore, non-parametric Mann-Whitney U test was run. The $p<0.05$ was determined as the significance level. The secondary data were analyzed in a descriptive manner.

## Results

Table 2 presents the $WI_D$ values of the groups at $T_0$, $T_1$ and $T_2$. There were no significant differences among the groups at $T_0$ and $T_1$ ($p>0.05$). However, significant differences were seen at $T_2$ in all tested resin composites. The highest $WI_D$ at $T_2$ was found in AHW and IOW for all tested resin composites.

The means and standard deviations (± SD) of $\Delta E1_{00}$ $\Delta E2_{00}$, and $\Delta E3_{00}$ values are shown in Table 3.

No significant differences were found among the whitening agents applied to the three resin composites tested in $\Delta E1_{00}$ ($p <0.05$), whereas there were significant differences in $\Delta E2_{00}$ and $\Delta E3_{00}$ ($p<0.05$). AHW and IOW produced higher color changes than PT, WP, WT and WMR for the tested

boja. L* je svjetlina, od bijele do crne (100 - 0), a* je crveno-zelena i b* je žuto-plava vrijednost na kromatskim koordinatama.

Mjerenja boje obavljena su u trima različitim vremenima – na početku (poslije 24 sata) ($T_0$), poslije bojenja ($T_1$) i poslije izbjeljivanja ($T_2$). Analize su provedene postavljanjem uzoraka na bijelu i crnu podlogu. Mjerenja boje provedena su tri puta u središtu gornje površine svakog uzorka i izračunat je prosjek.

Indeks izbjeljivanja (WID) izračunat je za $T_0$, $T_1$ i $T_2$ prema sljedećoj jednadžbi (20):

$$WI_D = 0.511L^* - 2.324a^* - 1.100b^*$$

Promjena boje ($\Delta E_{00}$) izračunata je prema $CIEDE_{2000}$ (21, 22).

Parametar translucencije (TP) izračunat je s pomoću sljedeće jednadžbe (23, 24):

$$TP = \left[(L_B^* - L_W^*)^2 + (a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2\right]^{1/2}$$

U ovoj jednadžbi, koordinate boje $L_W$ $a_W$ $b_W$ dobivene su u odnosu na bijelu pozadinu, a $L_B$ $a_B$ $b_B$ dobiveni su u odnosu na crnu (28). TP u rasponu između 0 – 100 i više znači povećanu prozirnost, a niže vrijednosti TP-a znače povećanu neprozirnost (27). Izračunata je translucencija uzoraka poslije 24 sata ($T_0$), poslije bojenja ($T_1$) i poslije izbjeljivanja ($T_2$).

Razlika u TP (ΔTP) izračunata je s pomoću sljedeće jednadžbe (28):

ΔTP1 = $TP_1 – TP_0$ (bojenje – početna vrijednost)
ΔTP2 = $TP_2 – TP_1$ (izbjeljivanje – bojenje)
ΔTP3 = $TP_2 – TP_0$ (izbjeljivanje – početna vrijednost)

### Statistička analiza

Za analizu je upotrijebljen statistički softver SPSS 20.0 (Superior Performing Software Systems, Chicago, SAD). Za svaku skupinu izračunata je srednja vrijednost boje i translucencija u različitim razdobljima istraživanja sa standardnom devijacijom i 95-postotnim intervalima pouzdanosti. Kolmogorov-Smirnovljev test pokazao je da je distribucija podataka bila nehomogena. Zato je primijenjen neparametrijski Mann-Whitneyjev U test zbog asimetrične distribucije podataka. Kao razina značajnosti određen je $p < 0,05$. Sekundarni podatci analizirani su deskriptivno.

## Rezultati

U tablici 2. nalaze se vrijednosti $WI_D$ grupa za $T_0$, $T_1$ i $T_2$. Nije bilo značajnih razlika između skupina za $T_0$ i $T_1$ ($p > 0,05$). Ali značajne razlike uočene su za $T_2$ kod svih testiranih kompozitnih smola. Najveći $WI_D$ za T2 ustanovljen je kod AHW-a i IOW-a za sve testirane kompozitne smole.

Srednje vrijednosti i standardne devijacije (± SD) $\Delta E1_{00}$ $\Delta E2_{00}$ i $\Delta E3_{00}$ prikazane su u tablici 3.

Nisu pronađene značajne razlike među sredstvima za izbjeljivanje primijenjenima na trima testiranima kompozitnim smolama za $\Delta E1_{00}$ ($p <0,05$), a zabilježene su značajne razlike za $\Delta E2_{00}$ i $\Delta E3_{00}$ ($p < 0,05$). AHW i IOW prouzročili su veće promjene boje nego PT, WP, WT i WMR za testirane kompozitne smole.

**Table 2** Mean $WI_D$ values ± standard deviations (± SD) of the resin composites tested
**Tablica 2.** Srednje $WI_D$ vrijednosti ± standardne devijacije (± SD) testiranih kompozitnih smola

| | $WI_D$ ($T_0$) | $WI_D$ ($T_1$) | $WI_D$ ($T_2$) | p |
|---|---|---|---|---|
| G-Ant | | | | |
| C | 3.05±1.17 | - | 3.23±1.42[a] | 0.999 |
| IOW | 3.41±1.5 | -3.21±1.08 | 3.34±3.34[a] | <0.001[+] |
| AHW | 2.97±1.03 | -3.88±1.71 | 3.40±1.14[a] | <0.001[+] |
| PT | 3.34±1.17 | -3.78±1.42 | 2.25±3.76[b] | <0.001[+] |
| WP | 3.12±1.48 | -4.11±0.76 | 3.06±0.92[b] | <0.001[+] |
| WT | 2.67±0.8 | -4.14±0.89 | 2.42±1.98[b] | <0.001[+] |
| WMR | 2.42±0.77 | -4.65±1.42 | 2.35±1.46[b] | <0.001[+] |
| p | >0.05* | >0.05* | <0.001** | |
| G-Post | | | | |
| C | 16.27±0.32 | | 12.26±0.49[a] | -0.01 |
| IOW | 14.77±0.71 | -6.11±4.76 | 12.99±3.68[b] | 0.002[++] |
| AHW | 16.38±0.59 | -7.18±2.55 | 14.97±3.37[d] | <0.001[+] |
| PT | 16.12±1.22 | -6.14±5.42 | 12.01±1.81[b] | <0.001[+] |
| WP | 17.01±0.21 | -7.12±5.33 | 12.11±2.66[d] | <0.001[+] |
| WT | 17.76±0.18 | -7.63±6.02 | 12.22±2.69[c] | <0.001[+] |
| WMR | 17.74±0.82 | -6.41±4.36 | 11.50±4.06[c] | <0.001[+] |
| p | >0.05* | >0.05* | <0.001** | |
| G-ACH | | | | |
| C | 8.51±1.23 | | 7.59±1.44[a] | 0.876[+] |
| IOW | 8.12±1.2 | -7.71±3.76 | 7.96±3.41[b] | 0.004[++] |
| AHW | 7.76±1.04 | -9.31±3.18 | 10.80±2.47[c] | 0.009[+] |
| PT | 7.34±0.86 | -8.42±2.55 | 7.13±1.57[b] | 0.009[+] |
| WP | 8.78±1.65 | -8.65±4.59 | 5.97±3.12[d] | 0.010[++] |
| WT | 9.11±1.76 | -8.54±3.21 | 7.07±1.99[b] | 0.034[++] |
| WMR | 7.55±0.96 | -7.79±4.34 | 4.47±2.31[e] | <0.001[+] |
| p | >0.05* | >0.05* | <0.001** | |

$T_0$: after 24 h, $T_1$: after staining, $T_2$: after whitening • $T_0$: poslije 24 h, $T_1$: poslije bojenja, $T_2$: poslije izbjeljivanja
*One-way ANOVA, **Kruskal-Wallis H test. +Paired samples t-test ++Wilcoxon Signed Rank test • *Jednosmjerna ANOVA, **Kruskal-Wallisov H test. + T-test uparenih uzoraka ++Wilcoxonov test sume rankova

resin composites.

The In G-Ant, $\Delta E2_{00}$ and $\Delta E3_{00}$ values were as; AHW, IOW > PT, WP WT >WMR. In G-Post, the $\Delta E2_{00}$ and $\Delta E3_{00}$ values were as follows: AHW, IOW > PT, WP > WT, WMR. In G-ACH, the $\Delta E2_{00}$ values were in the following order as; AHW > IOW > PT, WP, WT, WMR. The $\Delta E3_{00}$ values were as: AHW, IOW > WP, PT, WMR, and WT.

The means and standard deviations (± SD) of TP0, TP1, TP2 and $\Delta TP_1$, $\Delta TP_2$, and $\Delta TP_3$ values are presented in Table 4. No significant differences were detected among TP0, TP1 and TP2 except for IOW and AHW in G-Ant (p= 0.033, 0.032), respectively. All whitening agents tested showed no significant differences in G-Ant for TP0, TP1 and $\Delta TP_1$, $\Delta TP_2$ and $\Delta TP_3$ (p>0.05). TP2 values of IOW and AHW were higher than PT, WP, WT and WMR. No significant differences were found among whitening agents for G-Post at TP0, TP1, TP2 and $\Delta TP_1$ and $\Delta TP_2$ but there were significant differences in ΔTP3 (p=0.003). The results revealed no differences among the whitening agents for G-ACH in TP0, TP1, TP2 and ΔTP1, but significant differences were observed for ΔTP2 and ΔTP3 (p=0.008, p=0.0.15, respectively).

Za G-Ant, vrijednosti $\Delta E2_{00}$ i $\Delta E3_{00}$ bile su: AHW, IOW > PT, WP WT > WMR.

Za G-Post vrijednosti $\Delta E2_{00}$ i $\Delta E3_{00}$ bile su: AHW, IOW > PT, WP > WT, WMR.

Za G-ACH vrijednosti $\Delta E2_{00}$ bile su sljedeće: AHW > IOW > PT, WP, WT, WMR.

Vrijednosti $\Delta E3_{00}$ bile su: AHW, IOW > WP, PT, WMR, WT.

Srednje vrijednosti i standardne devijacije (± SD) za $TP_0$, $TP_1$, $TP_2$ i $\Delta TP_1$, $\Delta TP_2$ i $\Delta TP_3$ prikazane su u tablici 4. Nisu ustanovljene značajne razlike između $TP_0$, $TP_1$ i $TP_2$ osim za IOW i AHW za G-Ant ( p = 0,033, 0,032). Sva testirana sredstva za izbjeljivanje nisu pokazala značajne razlike G-Anta za $TP_0$, $TP_1$ i $\Delta TP_1$, $\Delta TP_2$ i $\Delta TP_3$ (p > 0,05). $TP_2$-vrijednosti za IOW i AHW bile su veće od PT-a, WP-a, WT-a i WMR-a. Nisu ustanovljene značajne razlike među sredstvima za izbjeljivanje kod G-Posta za $TP_0$, $TP_1$, $TP_2$ i $\Delta TP_1$ i $\Delta TP_2$, ali postoje značajne razlike za $\Delta TP_3$ (p = 0,003). Rezultati nisu otkrili razlike među sredstvima za izbjeljivanje kod G-ACH-a za $TP_0$, $TP_1$, $TP_2$ i $\Delta TP_1$, ali su značajne razlike uočene za $\Delta TP_2$ i $\Delta TP_3$ (p = 0,008, p = 0,0,15).

**Table 3** Mean $\Delta E_{00}$ values ± standard deviations (± SD) of the resin composites tested
**Tablica 3.** Srednje $\Delta E_{00}$ vrijednosti ± standardne devijacije (± SD) testiranih kompozitnih smola

| | $\Delta E1_{00}$ | $\Delta E2_{00}$ | $\Delta E3_{00}$ | p |
|---|---|---|---|---|
| G-Ant | | | | |
| C | - | - | 0.39±0.23[a] | - |
| IOW | 4.40±0.37 | 4.61±0.50[a] | 3.93±0.87[b] | <0.001[++] |
| AHW | 4.42±0.34 | 5.08±0.76[a] | 3.94±0.81[b] | <0.001[+] |
| PT | 4.44±0.32 | 3.76±0.75[b] | 3.46±0.79[c] | 0.001[+] |
| WP | 4.43±0.30 | 3.78±0.68[b] | 3.53±0.63[c] | 0.017[++] |
| WT | 4.41±0.34 | 3.66±0.75[b] | 3.57±0.46[c] | 0.026[+] |
| WMR | 4.41±0.35 | 3.33±0.50[c] | 3.27±0.23[d] | 0.001[+] |
| *p* | >0.05* | <0.001** | <0.001** | |
| G-Post | | | | |
| C | | | 0.53±0.33[a] | - |
| IOW | 8.11±2.41 | 6.83±2.38[a] | 5.07±1.68[b] | <0.001[+] |
| AHW | 8.16±2.50 | 7.04±1.85[b] | 5.17±1.40[b] | <0.001[++] |
| PT | 8.07±2.55 | 5.25±1.77[c] | 4.18±1.31[c] | <0.001[+] |
| WP | 8.06±2.53 | 5.03±1.51[c] | 3.61±0.79[c] | <0.001[+] |
| WT | 8.06±2.49 | 3.64±0.61[d] | 2.34±0.68[d] | <0.001[+] |
| WMR | 8.01±2.49 | 3.54±1.18[d] | 2.12±0.79[d] | <0.001[++] |
| p | >0.05* | <0.001*** | <0.001** | |
| G-ACH | | | | |
| C | | | 0.31±0.31[a] | |
| IOW | 5.59±2.81 | 6.00± 2.85[a] | 2.60±0.94[b] | <0.001[+] |
| AHW | 5.49±2.73 | 7.46±2.58[b] | 2.88±0.71[b] | <0.001[+] |
| PT | 6.08±2.46 | 5.21±1.99[c] | 1.54±1.01[c] | <0.001[++] |
| WP | 4.98±2.07 | 5.16±2.28[c] | 1.93±0.95[c] | <0.001[+] |
| WT | 4.85±2.37 | 4.98±2.80[c] | 1.43±0.54[c] | <0.001[+] |
| WMR | 5.68±3.07 | 4.93±2.02[c] | 1.44±0.95[c] | <0.001[+] |
| *p* | >0.05* | 0.006* | <0.001** | |

$\Delta E1_{00}$: Staining - Baseline ; $\Delta E2_{00}$:Whitening - Staining; $\Delta E3_{00}$: Whitening - Baseline • $\Delta E1_{00}$: bojenje – početna vrijednost ; $\Delta E2_{00}$:izbjeljivanje – obojenje; $\Delta E3_{00}$: izbjeljivanje – početna vrijednost
*One-way ANOVA **Kruskal-Wallis H test ***Welch test +One-way repeated measures ANOVA test ++Friedman test • *Jednosmjerna ANOVA **Kruskal-Wallisov H-test ***Welchov test + jednosmjerni ANOVA test ponovljenih mjerenja ++Friedmanov test

## Discussion

This *in vitro* study investigated the effect of different whitening agents on whiteness index, color change and translucency of different resin composites used for the restoration of anterior, posterior or both anterior and posterior teeth. Based on the results of the study, the null hypothesis was rejected since significant differences were found for whiteness index, color and translucency among the tested resin composites after application of whitening agents.

$WI_D$ is a simple linear formulation and mainly developed for dentistry to correlate the perception of tooth color and to avoid the subjective visual factor in dental color measurement(29). $WI_D$ can be calculated using the values of the three CIELAB values, and it has a simple interpretation: the higher the WID of a tooth / specimen (positive values) means, the whiter specimen /tooth, whereas lower or negative values indicate a departure from the white color (29, 30).

The analysis in the present study revealed that the whitening agents had a substantial effect on $WI_D$. Notably, there were significant changes in $WI_D$ of the resin composites after staining and application of whitening agents to the resin composite specimens. The observed impact can be attrib-

## Rasprava

U ovom istraživanju *in vitro* autori su ispitivali učinak različitih sredstava za izbjeljivanje na indeks bjeline, promjenu boje i translucenciju različitih kompozitnih smola koje se upotrebljavaju za restauraciju prednjih, stražnjih ili i prednjih i stražnjih zuba. Na temelju dobivenih rezultata odbačena je nulta hipoteza zato što su pronađene značajne razlike za indeks bjeline, boju i translucenciju među testiranim kompozitnim smolama poslije primjene sredstava za izbjeljivanje.

$WI_D$ jednostavna je linearna formulacija i uglavnom razvijena za stomatologiju kako bi se korelirala percepcija boje zuba i izbjegao subjektivni vizualni čimbenik u mjerenju njihove boje (26). $WI_D$ može se izračunati korištenjem vrijednosti triju CIELAB vrijednosti i ima jednostavno tumačenje: što je viši $WI_D$ indeks zuba/uzorka (pozitivne vrijednosti), to je bjelji uzorak/zub, a niže ili negativne vrijednosti upućuju na odstupanje od bijele boje (29, 30).

Analiza u ovom istraživanju otkrila je da su sredstva za izbjeljivanje imala znatan učinak na $WI_D$. Naime, dogodile su značajne promjene u $WI_D$ kompozitnih smola poslije bojenja i primjene sredstava za izbjeljivanje na uzorke kompozitnih smola. Opaženi utjecaj može se pripisati varijacijama u

**Table 4** Mean TP0, TP1, TP2 and $\Delta TP_1$, $\Delta TP_2$ and $\Delta TP_3$ values ± standard deviations (± SD) of the resin composites tested.
**Tablica 4.** Srednje vrijednosti $TP_0$, $TP_1$, $TP_2$ i $\Delta TP_1$, $\Delta TP_2$ i $\Delta TP_3$ ± standardne devijacije (± SD) testiranih kompozitnih smola

| | TP0 | TP1 | TP2 | p+ | $\Delta TP_1$ | $\Delta TP_2$ | $\Delta TP_3$ |
|---|---|---|---|---|---|---|---|
| G-Ant | | | | | | | |
| C | 11.54±1.46 | - | 10.62±1.00[a] | 0.96[a+] | - | - | -0.92±0.77 |
| IOW | 10.64±0.86 | 10.97±1.89 | 11.90±1.37[b] | 0.033[b+] | 0.99±1.45 | 0.27±1.87 | 1.26±1.80 |
| AHW | 9.96±0.75 | 10.03±1.49 | 11.62±1.00[ab] | 0.032[b+] | 0.07±0.26 | 1.22±1.81 | 0.99±1.40 |
| PT | 10.73±1.22 | 10.43±1.57 | 10.81±0.92[a] | 0.662[c+] | -0.3±0.67 | 0.38±1.80 | -0.3±0.31 |
| WP | 10.44±0.61 | 10.41±1.66 | 10.45±1.54[a] | 0.698[c+] | -0.03.98 | 0.05±2.43 | -0.18±0.59 |
| WT | 10.1±1.06 | 9.46±066 | 10.18±2.68[a] | 0.576[c+] | -0.64±1.81 | 1.59±2.77 | 1.66±1.71 |
| WMR | 10.34±0.11 | 10.40±1.03 | 10.66±1.18[a] | 0.963[a+] | -0.06±0.16 | 0.06±1.34 | 0.02±1.49 |
| p | >0.05* | >0.05* | 0.009** | | >0.05* | 0.241* | 0.053*** |
| G-Post | | | | | | | |
| C | 10.41±0.44 | | 10.12±0.82 | 0.904[+] | | | -0.29±0.94[a] |
| IOW | 11.19±1.42 | 11.22±2.34 | 10.89±1.66 | 0.110[+] | 0.03±0.08 | -0.33±3.10 | -0.3±1.61[b] |
| AHW | 9.87±0.56 | 9.93±1.41 | 9.58±2.45 | 0.499[+] | 0.06±0.47 | -0.35±4.74 | -0.29±1.35[b] |
| PT | 9.76±0.52 | 11.13±1.67 | 10.83±1.52 | 0.126[+] | 1.37±2.10 | -0.3±3.29 | -1.51±0.56[a] |
| WP | 11.38±0.29 | 9.48±1.85 | 9.88±1.88 | 0.740[+] | -1,9±2.13 | 0.4±3.94 | -0.21±2.11[b] |
| WT | 11.42±0.89 | 11.37±2.-71 | 9.56±1.17 | 0.074[+] | -0.05±1.05 | -1.81±2.69 | -1.86±2.47[a] |
| WMR | 9.97±0.75 | 9.12±2.16 | 9.47±2.43 | 0.465[+] | -0.85±2.68 | -0.5±3.16 | -0.61±2.79[a] |
| p | >0.05* | >0.05* | >0.05 | | >0.05* | 0.357* | 0.003** |
| G-ACH | | | | | | | |
| C | 9.73±1.76 | | 9.34±1.95 | 0.955[+] | | | -0.39±0.88[a] |
| IOW | 9.87±1.41 | 9.12±2.81 | 9.58±1.47 | 0.780[+] | 0.1±1.43 | 0.46±1.06[b] | -0.29±0.38[a] |
| AHW | 9.04±1.67 | 9.14±2.76 | 10.36±2.54 | 0.410[+] | 0.1±0.06 | 1.22±4.15[c] | 1.32±1.92[b] |
| PT | 10.45±1.42 | 9.75±2.56 | 9.44±1.14 | 0.052[+] | -0.7±1.36 | -0.31±1.11[a] | -1.01±1.16[b] |
| WP | 10.17±1.52 | 10.01±2.72 | 9.85±2.44 | 0.560[+] | 0.62±1.47 | -1.16±3.89[c] | -0.32±0.67[a] |
| WT | 10.21±1.29 | 10.36±2.82 | 8.83±1.48 | 0.482[+] | 0.97±3.21 | -1.53±3.96[a] | -1.38±1.68[b] |
| WMR | 9.06±1.21 | 9.12±2.31 | 8.85±1.44 | 0.430[+] | 0.06±0.88 | -0.27±0.58[b] | -0.21±0.29[a] |
| p | >0.05* | >0.05* | >0.05 | | >0.05* | 0.008** | 0.015*** |

T0: after 24 h, T1: after staining, T2: after whitening • $T_0$: poslije 24 h, $T_1$: poslije bojenja, $T_2$: poslije izbjeljivanja
$\Delta TP_1$: TP1 – TP0, $\Delta TP_2$: TP2 – TP1, $\Delta TP_3$: TP2 – TP0
*One-way ANOVA, **Kruskal-Wallis H test, ***Welch test. +Paired samples t-test • *Jednosmjerna ANOVA, **Kruskal-Wallisov H test, ***Welchov test. + T-test uparenih uzoraka

uted to variations in the sensitivity of the organic matrix of the studied resin composites to staining, as well as changes in the absorption and/or interaction mechanism of the staining solution.

The clinical acceptance threshold considered for $E\Delta_{00}$ is 1.8(23). Color changes beyond this threshold can be distinguished by an unskilled person and cannot be considered clinically acceptable (23, 31). During the process of whitening, free radicals oxidize the organic substances of the tooth (24). However, in case of resin composites, the agent can affect both, the resin matrix and the filler.

The current study found that the whitening agents tested resulted in significant color changes in all of the resin composites that were examined (p<0.05). IOW and AHW produced highest color change, followed by WP and / or PT and WMR and / or WT. This can be explained by longer duration of contact and higher concentrations of HP levels (40%, 10% CP) of IOW and AHW. Contrary to the results of this study, Kim et al. (32) detected no differences in color change regardless of the type of resin composite, whether nanofilled or microhybrid, after the application of a whitening film and a strip. However, some similar results to the present study were also reported in the literature (6, 33, 34). Canay and

osjetljivosti organske matrice proučavanih kompozitnih smola na bojenje, te promjenama u mehanizmu apsorpcije i/ili interakcije otopine za bojenje.

Prag kliničke prihvatljivosti koji se razmatra za $E\Delta_{00}$ jest 1,8 (23). Promjenu boje iznad toga praga može uočiti i nestručna osoba i ne mogu se smatrati klinički prihvatljivima (23, 31). Tijekom procesa izbjeljivanja slobodni radikali oksidiraju organske tvari zuba (24), ali u slučaju kompozitnih smola, sredstvo može utjecati i na smolastu matricu i na punilo.

U ovom istraživanju otkriveno je da su ispitana sredstva za izbjeljivanje rezultirala značajnim promjenama boje na svim testiranim kompozitnim smolama (p < 0,05). IOW i AHW proizveli su najveću promjenu boje, a zatim slijede WP i/ili PT i WMR i/ili WT. To se može objasniti duljim kontaktom i višim koncentracijama HP-a (40 %, 10 % CP) na IOW i AHW. Suprotno rezultatima ovog istraživanja, Kim i suradnici (32) nisu otkrili nikakvu razliku u promjeni boje bez obzira na vrstu kompozitne smole, bilo nanopunjene ili mikrohibridne, poslije nanošenja filma za izbjeljivanje i trake. Međutim, u literaturi su također objavljeni rezultati slični onima u našem istraživanju (6, 33, 34). Canay i Cehreli (5) usporedili su učinak 10-postotnoga CP-a i 10-postotnoga HP-a na boju hibridnih kompozitnih smola s makropu-

Cehreli(6) compared the effect of 10% CP and 10% HP on the color of hybrid, macrofilled and polyacid-modified resin composites and showed that color change of tested resin composites whitened with 10% HP was clinically detectable to the naked eye. On the other hand, Monaghan et al.(33) compared the effects of two commercial whitening gels on the color of resin composite and reported that color change values were less than 2 or at the normal limit of visual acuity. No visual color change was evident for those resin composites. Another study of Monaghan et al. (34) investigating the color change of resin composite after four sessions of vital tooth whitening showed that highly concentrated office whitening agents changed the color of resin composites. In the present study, WP and PT produced the highest $\Delta E3_{00}$ values after IOW and AHW. This might be due to the whitening mechanism of the agents, as both WP and PT function in a similar manner, utilizing a 6% concentration of HP. Given the higher HP level in the IOW group, the product's superior whitening effectiveness aligns with the existing literature(35). However, in AHW, although this whitening agent contains lower HP than IOW, it showed similar $\Delta E3_{00}$ value. This finding is consistent with the study conducted by Mada et.al.(30).They reported no difference between whitening agents containing 6%, and 35% HP on the specimens stained with coffee. This could be attributed to the prolonged administration of the whitening application with duration of 8 hours each day over a span of 14 days. The color change was lower in the resin composite used for the restoration of anterior teeth than the changes in other tested resin composites. The minimal color change can be attributed to the polishability of this anterior material which retained smoother surface texture after finishing and polishing. The literature demonstrates that the composition of the organic matrix and the properties of the filler particles in the resin matrix directly influence the smoothness of the surface and its vulnerability to external stains (36).

The effectiveness of whitening toothpastes and mouthrinses was extensively studied through comparisons with regular toothpastes and whitening strips (37-42). Nevertheless, there was a lack of consensus regarding the efficacy of these whitening products. Although Roopa et al.(37) and Yazdi et al.(42) observed a significant color change in resin composite after brushing with whitening toothpastes, or after exposure to whitening mouth rinses, Celik et al.(43) reported no clinically perceivable color change after immersion in mouthrinses. Oliveira et al. (41) compared the effectiveness of whitening mouthrinses on teeth previously whitened or not whitened and exposed to food dyes and revealed no whitening similar to 10% CP after subjecting to different mouthrinses. In the present study, WT and WMR produced the lowest whitening in all groups. WMR contains only 2% HP and the whitening mechanism of WT tested in the present study depends on removal of the extrinsic stains by silica.

Previous research has established that if a material has a sufficient light diffusivity, a chameleon effect could be obtained due to the reflection of the adjacent tooth color and transference of its own color into the nearby tooth structure. Resin composites have a remarkable light diffusivity, such as trans-

njenjem i polikiselinom modificiranih smola i pokazali da je promjena boje testiranih kompozitnih smola izbijeljenih 10-postotnim HP-om bila klinički vidljiva golim okom. S druge strane, Monaghan i suradnici (33) usporedili su učinke dvaju komercijalnih gelova za izbjeljivanje na boju kompozitnih smola i izvijestili da su vrijednosti promjene boje manje od dva ili na granici vidljivosti. Za te kompozitne smole nije bila vidljiva nikakva vizualna promjena boje. U drugom istraživanju Monaghana i suradnika (34) ispitivala se promjena boje kompozitnih smola nakon četiriju seansa izbjeljivanja vitalnih zuba i pokazalo je da visoko koncentrirana sredstva za ordinacijsko izbjeljivanje mijenjaju boju kompozitnih smola. U ovom istraživanju, WP i PT proizveli su najviše vrijednosti $\Delta E3_{00}$ na IOW i AHW. To bi moglo biti zbog mehanizma izbjeljivanja sredstava, s obzirom na to da WP i PT djeluju slično zbog 6-postotne koncentracije HP-a. S obzirom na višu razinu HP-a u skupini IOW, veća učinkovitost izbjeljivanja u skladu je s postojećom literaturom (35). No AHW je unatoč nižem sadržaju HP-a od IOW-a, pokazao sličnu vrijednost $\Delta E3_{00}$. Taj je nalaz u skladu s istraživanjem koje su proveli Mada i suradnici (30). Oni su izvijestili da nema razlike između sredstava za izbjeljivanje koja sadrže 6-postotni i 35-postotni HP na uzorcima obojenima kavom. To se može pripisati produženoj primjeni sredstva za izbjeljivanje u trajanju od 8 sati svaki dan tijekom 14 dana. Promjena boje bila je manja na kompozitnoj smoli korištenoj za restauraciju prednjih zuba od promjena na drugim testiranim kompozitnim smolama. Minimalna promjena boje može se pripisati mogućnosti poliranja toga materijala koji je zadržao glađu teksturu površine nakon završne obrade i poliranja. Literatura pokazuje da sastav organske matrice i svojstva čestica punila u smolastoj matrici izravno utječu na glatkoću površine i njezinu osjetljivost na vanjska obojenja (36).

Učinkovitost pasta za izbjeljivanje zuba i tekućina za ispiranje usta s učinkom izbjeljivanja opsežno je istraživana usporedbama s običnim pastama za zube i trakicama za izbjeljivanje (37 – 42). Unatoč tomu, nije postignut konsenzus o učinkovitosti tih proizvoda za izbjeljivanje, iako su Roopa i suradnici (37) te Yazdi i suradnici (42) uočili značajnu promjenu boje kompozitnih smola poslije pranja pastama za izbjeljivanje zuba ili poslije izlaganja tekućinama za ispiranje usta s učinkom izbjeljivanja. Celik i suradnici (43) pak nisu pokazali klinički uočljivu promjenu boje poslije uranjanja u tekućine za ispiranje usta. Oliveira i suradnici (41) usporedili su učinkovitost izbjeljivanja tekućina za ispiranje usta na prethodno izbijeljenim ili neizbijeljenim zubima koji su bili izloženi prehrambenim bojama i otkrili da nije bilo izbjeljivanja usporedivog s 10-postotnim CP-om nakon izlaganja različitim otopinama za ispiranje usta. U ovom istraživanju su WT i WMR prouzročili najmanji učinak izbjeljivanja u svim skupinama. WMR sadržava samo 2-postotni HP, a mehanizam izbjeljivanja WT-a ispitan u ovom istraživanju ovisi o uklanjanju vanjskih obojenja s pomoću silicija.

U dosadašnjim istraživanjima utvrđeno je da se, ako materijal ima dovoljnu difuziju svjetlosti, može postići kameleonski učinak zbog refleksije boje susjednoga zuba i prijenosa vlastite boje na obližnje zube. Kompozitne smole imaju izvanrednu difuziju svjetlosti, kao što je translucencija koja lucency resulting in improved color matching between the restorative material and the tooth (44, 45). Translucency can be defined as a middle state of opacity and transparency (16) and the relative quantity of light transmission or diffuse reflection from a material surface through a turbid medium(46). Translucency of resin composites had also been investigated in several comparative studies (46-49). Comparisons were made according to the type, brand or dentin, enamel, translucent incisal and opaque shades of resin composites (46-49).

The instability of color and translucency might impact the visual esthetic appearance of restoration, and a high level of translucency may necessitate its replacement (50). It was reported that visual perceptibility threshold for translucency difference in contrast ratio (ΔCR) of 0.07 could be transformed into ΔTP value of 2. This means that translucency of resin composite is perceivable when ΔTP > 2 (28).

Similarly, in the present study $\Delta TP_1$, $\Delta TP_2$ and $\Delta TP_3$ in G-Ant, G-Post or G-ACH did not exceed 2 and the differences were not perceivable. An increased TP values were detected with IOW and AHW in the resin composite used for the restoration of anterior teeth, whereas the other two resin composites presented similar TP2 values. Most likely, these results may be influenced by the color and whiteness index of the tested resin composites as higher $\Delta E_{00}$ and $WI_D$ values were achieved after the application of IOW and AHW. The reason why this change was higher in the G-Ant compared to the other two groups may be due to the lower filler load. Filler load of G-Ant is lower (73 wt %) than posterior (77 wt %) and universal resin composites (82 wt %). Having lower filler content may have resulted in greater light transmission along with more whitening of the material. Since fillers are basically glass, the influence of HP on fillers would be very small. Additionally, the concentrated or repeated application of HP can chemically degrade the resin matrix. Therefore, greater color change and a higher TP are reasonable.

The present study has certain limitations. It was conducted *in vitro* and the tested resin composites were consistently subjected to staining solutions. Daily brushing effect on the specimen surfaces was not evaluated during the staining process. In the oral cavity, the uneven surfaces of resin composite restorations placed in posterior pits, fissures and grooves of the teeth may not always be perfectly polished with polishing discs. Furthermore, this study tested the effectiveness of only one staining solution. The efficacy of various staining solutions may yield outcomes that differ from those obtained in the present study. Finally, although *in vitro* studies attempt to simulate clinical conditions, they should be supported with *in-vivo* studies.

## Conclusions

Clinicians should be aware of the fact that higher concentrations of hydrogen peroxide in whitening procedures can lead to more significant color changes in resin composites, particularly in anterior restorations with lower filler content. Patient education and informed decision-making are essential to strike a balance between achieving whiter teeth and preserving the esthetic integrity of dental restorations.

rezultira poboljšanim usklađivanjem boje između restaurativnog materijala i zuba (44, 45). Translucencija se može definirati kao srednji stupanj opaciteta i transparencije (16) i relativna količina prijenosa svjetlosti ili difuzije refleksija od površine materijala kroz zamućeni medij (46). Translucencija kompozitnih smola također je ispitivana u nekoliko komparativnih istraživanja (46 – 49). Usporedbe su rađene prema vrsti, marki ili optičkoj skupini (dentinska, caklinska, incizalna i neprozirna) kompozitnih smola (46 – 49).

Nestabilnost boje i translucencije može utjecati na estetski izgled restauracije, a visoka razina translucencije može zahtijevati njezinu zamjenu (50). Zabilježeno je da se prag vizualne percepcije razlike translucencije u omjeru kontrasta (ΔCR) od 0,07 može transformirati u vrijednost ΔTP od 2. To znači da je promjena translucencije kompozitne smole vidljiva kada je ΔTP > 2 (28).

Slično tomu, u ovom istraživanju $\Delta TP_1$, $\Delta TP_2$ i $\Delta TP_3$ za G-Ant, G-Post ili G-ACH nisu prelazili 2 i razlike nisu bile uočljive. Povećane vrijednosti TP-a otkrivene su za IOW i AHW za kompozitne smole korištene za restauraciju prednjih zuba, a druge dvije kompozitne smole pokazale su slične vrijednosti $TP_2$. Najvjerojatnije na te rezultate mogu utjecati indeks boje i bjeline testiranih kompozitnih smola s obzirom na to da su više vrijednosti $\Delta E_{00}$ i $WI_D$ postignute su nakon primjene IOW-a i AHW-a. Razlog zašto je ta promjena bila veća za G-Ant u usporedbi s drugim dvjema skupinama može biti niži sadržaj punila. Sadržaj punila u G-Ant-u manji je (73 wt %) nego u kompozitima za stražnje restauracije (77 wt %) i univerzalnim kompozitima (82 wt %). Niži sadržaj punila možda je rezultirao većom propusnošću svjetlosti, zajedno s jačim učinkom izbjeljivanja materijala. Budući da su punila u osnovi staklo, utjecaj HP-a na punila bio bi vrlo mali. Dodatno, koncentrirana ili ponovljena primjena HP-a može kemijski razgraditi smolastu matricu. Dakle, razumna je veća promjena boje, a time i viši TP.

Ovo istraživanje ima određena ograničenja – provedeno je *in vitro*, a testirane kompozitne smole dosljedno su podvrgnute otopinama za bojenje. Učinak svakodnevnog četkanja površine uzorka nije procijenjen tijekom procesa bojenja. U usnoj šupljini površine kompozitnih ispuna u stražnjim jamicama i fisurama zuba možda neće uvijek biti savršeno ispolirane diskovima za poliranje. Nadalje, u ovom istraživanju testirana je učinkovitost samo jedne otopine za bojenje. Učinkovitost različitih otopina za bojenje može dati rezultate koji se razlikuju od onih dobivenih u ovom istraživanju. Konačno, iako istraživanja *in vitro* pokušavaju simulirati kliničke uvjete, treba ih podržati istraživanjima *in vivo*.

## Zaključak

Kliničari trebaju biti svjesni da veće koncentracije vodikova peroksida u postupcima izbjeljivanja mogu značajnije promijeniti boju kompozitnih smola, osobito na prednjim ispunima s nižim sadržajem punila. Edukacija pacijenata i informirano donošenje odluka ključni su za dobivanje ravnoteže između postizanja bjeljih zuba i očuvanja estetskog integriteta postojećih restauracija.

## Conflict of interest

The authors report no conflict of interest

## Disclosure

The authors do not have any financial interest in the companieswhose materials are included in this article.

## Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**Doprinos autora:** **U. K. V., S. G., C. A.** – koncept; **U. K. V., S. G.** – metodologija, formalna analiza, pisanje izvornog nacrta; **U. K. V., C. A.** – istraživanje; **S. G.** – izvori; **U. K. V., S. G., C. A.** – strukturiranje podataka; **U. K. V., C. A.** – pisanje, pregled i uređivanje; **U. K. V.** – vizualizacija, administracija projekta: **I. M., S. G.** – supervizija.

**Sažetak**

**Svrha istraživanja:** Željelo se ispitati učinke različitih sredstava za izbjeljivanje na boju i translucenciju različitih kompozitnih smola *in vitro*. **Materijali i metode:** Ukupno 315 uzoraka (10,0 × 2,0 mm) proizvedeno je od dviju mikrohibridnih [G-aenial anterior (G-Ant)] i [G-aenial posterior (G-Post')], te nanohibridnih [G- aenial A'CHORD (G-ACH)] kompozitnih smola pa je svaka skupina nasumično raspoređena u sedam eksperimentalnih skupina (n = 15) kako slijedi: 1 – kontrola (C); 2 – sredstvo za izbjeljivanje u ordinaciji (IOW); 3 – sredstvo za kućno izbjeljivanje (AHW); 4 – prethodno napunjena udlaga (PT); 5 – olovka za izbjeljivanje (WP); 6 – pasta za izbjeljivanje zubi (WT); 7 – vodica za ispiranje usta s učinkom izbjeljivanja (WMW). Uzorci su bili obojeni, osim kontrolne skupine, prije primjene različitih postupaka izbjeljivanja. Boja uzoraka mjerena je poslije 24 sata ($T_0$), poslije bojenja ($T_1$) i poslije izbjeljivanja ($T_2$). Izračunate su promjene boje [$CIEDE_{2000}$ ($\Delta E_{00}$)], vrijednosti parametra translucencije (TP) i promjene indeksa bjeline (WID). Podatci su statistički obrađeni ($p < 0{,}05$). **Rezultati:** Nisu utvrđene značajne $WI_D$ razlike među testiranim kompozitnim smolama na $T_0$ i $T_1$ ($p > 0{,}05$), a značajna je razlika uočena na $T_2$ ($p < 0{,}005$). AHW i IOW prouzročili su veću promjenu boje nego PT, WP, WT i WMR. Značajne promjene TP-a uočene su nakon primjene IOW-a i AHW-a u G-Antu. **Zaključak:** Učinak proizvoda za izbjeljivanje na indeks izbjeljivanja, boju i translucenciju kompozitnih smola ovisi o materijalu i podlozi.

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**MeSH pojmovi:** sredstva za izbjeljivanje zubi; dugotrajni neželjenmi učinci; kompozitne smole; boja
**Autorske ključne riječi:** izbjeljivanje, indeks izbjeljivanja, boja, prozirnost, kompozitne smole

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