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IZVORNI ZNANSTVENI RAD
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Procjena mikropropuštanja između različitih sustava kolčića i nadogradnji u uvjetima postupnog opterećenja: istraživanje in vitro

Evaluation of Microleakage Between Different Post and Core Systems Under Gradual Loading: an In-Vitro Study

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Sažetak

Svrha: Istraživanje je usmjereno na usporedbu u razlici spojnog prodora boja između svjetlovodnih kolčića everStick, Parapost XP i Parapost i kontrolnih skupina pod postupnim opterećenjem. **Materijali i metode:** Šezdeset osam ljudskih maksilarnih trajnih sjekutića podijeljeno je u četiri skupine. Svaki uzorak endodontski je tretiran tehnikom instrumentacije i pripremljen za svaki sustav kolčića prema eksperimentalnim skupinama. Nakon toga kolčić je cementiran u korijenski kanal. Oblikovane nadogradnje od kompozitnog materijala cementirane su u laboratorijski izrađene metalne krunice. Svi su uzorci termociklirani, osim onih u kontrolnoj skupini. Sve su skupine podvrgnute postupnom opterećenju od 0 N do 50 N u 100 ciklusa. Uzorci su poprečno prerezani i izmjerene su dubine penetracije boje uzduž kolčića. Podatci su uneseni u SPSS ver. 22 i analizirani dvosmjernim testom ANOVA-e. **Rezultati:** Nije bilo značajne razlike u spojnom prodoru boje ni u jednoj skupini (p – vrijednost > 0,05). No zabilježena je značajna razlika u postotku prodora boje između svih skupina (p – vrijednost < 0,05); post-hoc usporedba pokazala je znatnu razliku između Fiber White skupine i one kontrolne (p – vrijednost = 0,009). **Zaključak:** U svim je skupinama u uzorke prodirala boja, ali postotak je bio značajan samo između Parapost Fiber Whitea i kontrolnih skupina.

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Ključne riječi
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Uvod

Trajnost endodontski tretiranih zuba veća je otkako su poboljšani endodontski i restaurativni postupci (1). Izrada kolčića i nadogradnji postaje dio terapije u endodontski tretiranim zubima jer poboljšavaju restauraciju i retenciju krunica te bolje prenose sile (2).

Kako bi se pokazalo da postavljanje kolčića koristi zubu, obavljena su mnogobrojna istraživanja da bi se vidjelo kako i koliko oni pridonose snazi rekonstruiranih dijelova i očuvanju preostale strukture zuba. Nekoliko studija bavilo se kolčićima i nadogradnjama i njihovu odnosu prema otpornosti na slamanje (3, 4), upotrijebljenim materijalima (2, 5 – 10), te obliku i sastavu kolčića (11 – 14), a provedeno je i mnogo više istraživanja o procjeni ishoda različitih sustava koji se upotrebljavaju. Ključno je bilo istraživanje o količini mikropro-

Introduction

The life span of endodontically treated teeth has been upgraded with advancements made in endodontic and restorative procedures (1). Fabrication of post and core becomes part of components in endodontically treated teeth as it gives better outcome to the restoration and facilitates crown retention and support (2).

In order to ensure that the placement of post is beneficial to the tooth, studies were carried out to see how it contributes to the strength of the restoration and preservation of the remaining tooth structure. There were multiple studies on performance of post and cores in relation to fracture resistance (3, 4), materials used (2, 5-10), shape and designs (11-14) and many more were conducted to evaluate the outcome of different systems used. A study on the amount of micro-

puštanja između sustava i zuba, kao o značajnom pokazatelju uspjeha konačne restauracije (9).

Mikropropuštanje se opisuje kao *difuziju bakterija, oralnih tekućina, iona i molekula u zub i između materijala za punjenje korijenskog kanala* ili *klinički nevidljiv prolazak bakterija, tekućina, molekula ili iona između zuba i restaurativnog materijala ili punila korijenskog kanala* (15). Apikalna brtva od 3 do 5 mm korijenskog punjenja kanala opisana je kao *upitna* u smislu sprječavanja mikrocurenja (12).

Zamor materijala koji se događa u strukturama podvrgnutima dinamičkom stresu navodi se kao uzrok mikropropuštanja. Taj se čimbenik mora uzeti u obzir jer mikropropuštanje može poslije uzrokovati sekundarni karijes koji negativno utječe na stopu preživljavanja zuba i uzrokuje neuspjeh u liječenju (3). U jednom drugom istraživanju ističe se da bakterije i endotoksini imaju svojstvo prodiranja u materijal za punjenje u liječenim korijenskim kanalima (13). Prodor bakterijskih toksina, oralnih tekućina i drugih iona izaziva rubnu obojenost, sekundarni karijes i granične frakture. Mikropropuštanje je najčešći uzrok neuspjeha kad je riječ o sustavima kolčića i nadogradnje, zbog odvajanja kolčića od unutarnje površine korijena (9). Taj gubitak retencije između kolčića i korijena može rezultirati vertikalnom frakturom korijena i to je najozbiljniji uzrok neuspjeha s nepovratnim posljedicama (16).

Istraživanje Junga i suradnika (2007.) pokazalo je testom prodora boje da postoji razlika u količini mikropropuštanja između skupina, a obavljen je nakon dinamičkog opterećenja i tijekom opetovanog opterećenja. U skupini s opetovanim opterećenjem nije uspjela adhezivna veza između strukture zuba i jezgre jer je boja prodrla u veće područje korijenskog dentina. Fogel (1995.) je procijenio nekoliko tvorničkih *post-core* sustava testom mikropropuštanja filtracije fluida i ustanovio da se ni jednim od ispitanih sustava ne može postići potpuno nepropusno brtvljenje.

Nekada su mogućnosti za kolčiće i nadogradnje bile ograničene pa je lijevana metalna nadogradnja bila jedini izbor za restaurativno liječenje teško oštećenih zuba (17). Trenutačno nema dokaza o prednosti sustava kolčića i adhezivne nadogradnje kad je riječ mikropropuštanju pod postupnim opterećenjem. Zato je svrha ovog eksperimentalnog istraživanja bila usporediti razlike u rubnom prodoru boje između triju vrsta kolčića pod postupnim opterećenjima (everStick post, Parapost XP, Parapost Fiber White) i kontrolnih skupina.

Materijali i metode

Istraživanje je obavljeno u Maksilofacijalnom laboratoriju Stomatološkog fakulteta Sveučilišta Sains u Maleziji (USM). Veličina uzorka izračunata je korištenjem PS softvera (Dupont i Plummer, 1997.) na temelju standardne devijacije (σ) prosječnog gama-broja na 7,33 (8) s 80 % snage i alfom od 0,05. U svakoj skupini bilo je petnaest zuba. Uz pretpostavku da bi 10 % uzoraka iz svake skupine moglo biti problematično tijekom postupka, bilo je 17 zuba u svakoj, što je ukupno 68 zuba u cijelom istraživanju. Svi zubi dobiveni su u državnim i privatnim stomatološkim klinikama u Maleziji.

leakage between the system and the tooth was crucial for the success of the final restoration (9).

Microleakage is defined as the "diffusion of the bacteria, oral fluids, ions and molecules into the tooth and the filling material interface" or "the clinically undetectable passage of bacteria, fluids, molecules or ions between tooth and the restorative or filling material" (15). The presence of 3 to 5mm apical seal was reported to be "questionable" in terms of preventing microleakage (12).

Fatigue that happens in the structures subjected to dynamic stress was reported to cause microleakage clinically. This factor needs to be considered as microleakage will later cause secondary caries formation that will affect the survival rate and cause failure of the treatment itself (3). Other study reported that bacteria and endotoxins had the ability to penetrate the obturating materials in the post prepared root canals (13). The penetration of bacterial toxins, oral fluids, and other ions will lead to marginal discoloration, secondary caries and marginal fractures. Microleakage had been reported to be the most frequent cause of failure for the post and core system because of the separation of the post from the internal root surface (9). This loss of retention between the post and the root may lead to vertical root fracture, which was the most severe cause of failure with irreversible consequences (16).

A study by Jung *et al.* (2007) found that there was a difference in the amount of microleakage between group with the dye penetration test performed after dynamic loading and during the repeated loading. The group with repeated loading showed the adhesive failure between the tooth structure and the core where the dye penetrated into a larger area of root dentin. Fogel (1995) evaluated several prefabricated post and core systems with fluid filtration microleakage test and found that none of the systems tested were capable of consistently achieving fluid-tight seal.

In the past, the options for post and core were limited and cast metal post was the only practicable choice for the restorative treatment of severely damaged teeth (17). At present, there was lack of evidence with regard to superiority of the post and core systems related to microleakage under gradual loading. Thus, the aim of this experimental research was to compare the difference in marginal dye penetration between three types of posts under gradual loadings (everStick post, Parapost XP, Parapost fiber white) and control groups.

Materials and methods

The study was conducted at Craniofacial Laboratory of the School of Dental Sciences, Health Campus University Sains Malaysia (USM). The sample size was calculated using PS software (Dupont and Plummer, 1997) based on the standard deviation (σ) of the mean gamma count at 7.33 (8) with 80% power and alpha of 0.05. Fifteen teeth were needed in each study group. With anticipation of 10% of the samples from each group which could pose problems during the procedure, 17 teeth were included in each group, to make a total of 68 teeth in this study. All teeth were collected from government and private dental clinics in Peninsular Malaysia.

Korišteni su trajni maksilarni sjekutići s jednim ravnim korijenskim kanalom, bez karijesnih lezija ili zubi s karijesom bez zahvaćene pulpe te ograničeni na 2 mm incizalno od cementno-caklinskog spoja (CEJ) s formiranim apeksom ili zubi izvađeni zbog parodontne indikacije i oni bez napuklina i defekata. Kriteriji za isključivanje uključivali su zube s dodatnim korijenskim kanalom, otvorenim apeksom, kalcificiranim kanalom, zakrivljenim korijenima i korijenima s vanjskom resorpcijom. Kolčići korišteni u istraživanju prikazani su u tablici 1. Za cementiranje kolčića i krunica u ovoj studiji upotrijebljen je cement Rely X U200 (3M ESPE, SAD).

The human permanent maxillary incisors with straight single-rooted canal, non-carious or carious teeth without pulpal involvement and that limited to 2mm incisal to cementoenamel junction (CEJ) with mature apices or the teeth that were extracted due to periodontal problem and those free from cracks and defects were included in this study. Exclusion criteria included teeth with extra canal, open apices, calcified canal, curved roots, and resorbed roots. The posts used in this study are as shown in Table 1. Rely X U200 (3M ESPE, USA) cement was used to cement the posts and crowns in this study.

Tablica 1. Vrste kolčića korištenih u istraživanju
Table 1 Types of posts used in the study.

Ime proizvoda • Brand	Sastav • Composition	Proizvođač • Manufacturer
Parapost XP (P780)	Nehrđajući čelik • Stainless steel	Coltane Whaledent, SAD • USA
Parapost Fiber White (PF160)	Jednosmjerno stakleno vlakno / smola • Unidirection glass fiber/resin	Coltane Whaledent, SAD • USA
everStick	Smolom impregnirana nepolimerizirana staklena vlakna • Resin-impregnated uncured glass fiber	Stick Tech Ltd, Turku, Finska • Finland

Priprema uzoraka

Priprema korijenskog kanala

Sve vanjske strugotine uklonjene su ultrazvučnim skalerom, a zubi su odloženi u fiziološku otopinu. Kruna zuba je uklonjena okomito na uzdužnu osovinu zuba dijamantnim fisurnim svrdlom uz vodeno hlađenje (Horico, Njemačka) ručno-zračnom turbinom (Bien Air Dental SA, Švicarska), ostavljajući samo 2 mm koronalnog dijela incizalno na cementno-caklinskom spoju (CEJ) bukalne površine.

Ravan ulazak u koronalnu trećinu kanala postignut je dijamantnim fisurnim svrdlom uz vodeno hlađenje (Horico, Njemačka) ručno-zračnom turbinom (Bien Air Dental SA, Švicarska). Svi korijenski kanali instrumentirani su na radnoj duljini tehnikom Step Backa. Radna duljina zuba dobivena je u kanalu instrumentom broj 10 sve dok se nije pojavio na vrhu korijena, a zatim se od izmjerene duljine oduzelo 0,5 mm. Irigacija je obavljena 2,5-postotnim natrijevim hipokloritom, naizmjenično je isprana fiziološkom otopinom između obrade različitim veličinama instrumenata, a kanali su posušeni papirnatim šiljcima.

Kanali su instrumentirani Master Apical Fileom veličine 45 za Parapost XP, Parapost Fiber White i kontrolne skupine, a za everStick je veličina Master Apical Filea bila 55. Priprema kanala za sve skupine nastavljena je korištenjem triju instrumenata s većim promjerima, uz oduzimanje 1 mm između svakog instrumenta. Korijenski kanal napunjen je gutaperkom (Meta Biomed, Južna Koreja) i AH26 bez eugenola (Dentsply, SAD). Radiogram je snimljen za svaki uzorak kako bi se osiguralo da punjenje u kanalu nije homogeno. 24 sata poslije početka instrumentacije, u skupinama Parapost XP, Parapost Fiber White i everStick gutaperka je iz kanala uklonjena svrdlima Gates Glidden (Dentsply, Švicarska) veličine 2 i 3, a ostavljeno je samo 5 mm na vrhu korijena za apikalnu brtvu.

Prostori za kolčiće pripremljeni su za svaki sustav odgovarajućim svrdlima Parapost XP i Parapost Fiber White

Specimens Preparation

Root canal preparation

All external debris was removed with an ultrasonic scaler and the teeth were stored in normal saline solution. The coronal section of the teeth were amputated horizontally to the long axis using water cooled diamond fissure bur (Horico, Germany) in air turbine handpiece (Bien Air Dental SA, Switzerland), leaving only 2mm of the coronal part incisal to the cementoenamel junction (CEJ) from the buccal surface.

Straight-line access into the coronal third of the canal was made using water cold diamond fissure bur (Horico, Germany) in air turbine handpiece (Bien Air Dental SA, Switzerland). All root canals were instrumented at a working length using the step-back technique. The working length of the teeth was obtained by inserting number 10 file into the canal until it appeared at the apex of the root, then 0.5mm was subtracted from the total length. Intermittent irrigation was made with 2.5% sodium hypochlorite, rinsed with saline solution between file sizes and the canals were dried with paper points. The canals were prepared until Master Apical File size of 45 for Parapost XP, Parapost fiber white and control groups, whereas for everStick group the Master Apical File the size was 55. The canal preparation for all groups was continued using 3 sizes of larger files with substraction of 1 mm between each file. Obturation was done using the gutta percha (Meta Biomed, South Korea) and AH26 eugenol free sealer (Dentsply, USA). A radiograph was taken for each specimen to ensure there was no air bubbles present in the canal. After 24 hours of the initial preparation, the gutta percha points in Parapost XP, Parapost fiber white and everStick groups were removed using Gates Glidden (Dentsply, Switzerland) size 2 and size 3 leaving only 5mm at the apex of the root as an apical seal.

The post spaces were prepared for each system with Parapost XP drill and Parapost Fiber White (PF160) drill (Coltane Whaledent, USA). Post space preparation for ever-

(PF160) (Coltane Whaledent, SAD). Priprema prostora za kolčiće everStick obavljena je svrdlom Parapost Fiber White (PF160). Kolčići za sustave Parapost XP i Parapost Fiber White (PF160) postavljeni su nakon pripreme kanala na duljine s dodatna 2 mm iznad koronarnog ruba. Za svaki uzorak duljina je bila 4 mm od CC spoja. Zbog standardizacije veličine i duljine kolčića korištene su preporuke Fernandesa i Dessaia (2001.), pa je odabrana duljina kolčića bila tri četvrtine ukupne duljine korijena za svaki uzorak, a veličina kolčića manja od jedne trećine promjera korijena ili što je moguće bliže toj vrijednosti. Postupak koji se temelji na izvješću Le Bell-Rönnlöfa i suradnika (2011.) primijenjen je na skupinu EverStick. Paketi vlakana od 1,2 mm bili su smješteni u kanal, oba kraja vlakana su izrezana kako bi virili 2 mm incizalno iz koronarnog otvora. Vlakna su tada svjetlosno polimerizirana 40 sekunda (Mini L.E.D OEM, Francuska). Zatim su uklonjena i ponovno osvijetljena izvan kanala još 40 sekunda. Nakon toga postavljeni su i pričvršćeni dodatni snopovi pokraj oblikovanog snopa od 1,2 mm dok se kolčići i nadogradnje nisu prilagodili stijenci kanala i bili svjetlosno polimerizirani. Adaptacija nadogradnji unutar kanala potvrđena je rendgenskom snimkom.

Cementiranje svih tipova kolčića obavljeno je samojetkajućim kompozitnim cementom (Rely X U200, SAD) primijenjenim prema uputama proizvođača.

Za kontrolnu skupinu nije obavljena nikakva priprema za kolčić. Jezgra je pripremljena s 2 mm zdrave strukture zuba i uključena u rub preparacije.

Izrada krunice

Nadogradnja je pripremljena za svaki uzorak s pomoću kompozitne smole (Filtek ™ Z350 XT, SAD). Vodoravna površina koronarnog područja svakog uzorka najprije je jetkana 32-postotnom fosfornom kiselinom (Scotchbond ™ Universal Etchant, SAD) 15 sekunda, a zatim je isprana i osušena. Svaki je zub premazan adhezivnim sredstvom (3M ESPE Adper Single Bond Plus, SAD) i osvijetljen 10 sekunda, nakon čega je slijedilo postupno postavljanje kompozitne smole te je svaki sloj polimeriziran 40 sekunda. Metalne krunice izrađene u laboratoriju upotrijebljene su kao konačne restauracije i učvršćene su samojetkajućim kompozitnim cementom (Rely X U200, SAD) prema uputama proizvođača.

Testiranje materijala

Svaki uzorak premazan je trima slojevima komercijalnog laka za nokte i to od apeksa do cementno-caklinske granice da bi se spriječilo mikropropuštanje apeksa. Sve grupe su podvrgnute termocikliranju od 2000 ciklusa u vodenoj kupelji od 5 do 55 °C i u svaku su kupku uranjane po 20 sekunda. Kolčići everStick post, Parapost XP, Parapost fiber white groups postavljeni su na 135 stupnja u odnosu prema dužinskoj osovini zuba i opterećeni postupno od 0 do 50 N tijekom 100 ciklusa (Instron, Ujedinjeno Kraljevstvo) (20). Test postupnog opterećenja nije primijenjen u kontrolnoj skupini.

Testiranje mikropropuštanja

Nakon opterećenja su everStick post, Parapost XP, Parapost Fiber White i kontrolna skupina uronjeni u 2-postotnu

Stick post was done with Parapost Fiber White (PF160) drill. The posts for Parapost XP and Parapost Fiber White (PF160) were placed in the canals following the canal length prepared with additional of 2mm above the coronal margin. The total length was 4mm from CEJ for each specimen. The recommendation from Fernandes and Dessai (2001) was followed in order to standardize the size and length of the post where the post lengths used were three-quarters of the total root length for each specimen, and the post size was smaller than one-third of the root diameter or as close as possible to this value. The procedure based on report from Le Bell-Rönnlöf *et al.* (2011) was applied to the everStick group. The bundle fibers of 1.2mm were fitted in the canal, both end were cut to fit leaving 2mm of fiber incisal to the coronal opening. The fibers were then light-polymerized using a light curing device for 40 seconds (Mini L.E.D OEM, France). Next, the fibers were removed and light-cured again outside the canal for another 40 seconds. After that, the additional bundles were fitted next to and attached to the individually formed 1.2mm bundle until the posts were properly fitted in the canal and light cured. The fitting of the posts inside the canals was confirmed with a radiograph. Cementations of all types of posts were performed using self-adhesive resin luting cement (Rely X U200, USA). The resin cement application was based on the manufacturer's guidelines.

For the control group, no post space preparation was carried out. The core was prepared with 2mm of sound tooth structure, which was included at the margin of the preparation.

Crown Fabrication

A core built up for each specimen was done using composite resin (Filtek™ Z350 XT, USA). The horizontal surfaces of the coronal area of each specimen were firstly etched using 32% phosphoric acid (Scotchbond™ Universal Etchant, USA) for 15 seconds and then washed and dried using triplex syringe. Each tooth was continued with application of bonding agent (3M ESPE Adper Single Bond Plus, USA) and light-cured for 10 seconds followed by composite resin placement incrementally where each layer were light-cured for 40 seconds. Laboratory fabricated metal crowns were used as final restorations and cemented using self-adhesive resin luting cement (Rely X U200, USA) application based on the manufacturer's guidelines.

Material Testing

Each specimen was coated with 3 layers of commercial nail varnish from the apex to the CEJ level to prevent microleakage at the apex. All groups were subjected to thermal cycling of 2000 cycles in 5°-55°C water bath with a dwell time of 20 seconds in each bath. The everStick post, Parapost XP, Parapost fiber white groups were positioned at 135 degrees to the long axis of the tooth and were loaded for gradual loading from 0N to 50N for 100 cycles (Instron, United Kingdom) (20). The gradual loading test was not performed for the control group.

Marginal leakage testing

After the loading, the everStick post, Parapost XP, Parapost fiber white and the control group were immersed in 2%

metilenski plavu boju tijekom 24 sata na sobnoj temperaturi (21) zatim su isprani tekućom vodom da se ukloni suvišak boje. Svi su zubi prerezani transverzalno od spoja nadogradnje i zuba prema apeksu (Exact, Njemačka) te promatrani stereomikroskopom pod povećanjem od 30 puta (Leica, Njemačka). Deskriptivna mjerenja obavljena su na temelju fotografija prerezanih zuba na kojima je mjerena prisutnost i/ili dubina prodora boje, uz preparaciju za kolčić u milimetrima. Izračunat je omjer prodora boje u odnosu prema cijelom presjeku i zabilježen dobiveni postotak.

Statistička analiza

Za statističku analizu podataka korišten je program Statistical Package for the IBM Social Sciences (SPSS) version 22.0. Za parametrijsku analizu odabran je Kruskal-Wallisov test sa svrhom određivanja i usporedbe srednje vrijednosti dubine prodiranja boje između skupina everStick, parapost XP, parapost Fiber White i kontrolne, a dvosmjerna ANOVA primijenjena za određivanje i usporedbu postotka prodora boje u te skupine. Srednja vrijednost testirana je za značajnost s pomoću p-vrijednosti i višestrukom usporedbom post-hoc testa (Scheffeova). Vrijednost p postavljena je na razinu značajnosti $p < 0,05$.

Etičko dopuštenje

Istraživanje je odobrilo Etičko povjerenstvo za znanstvena i etička pitanja USM-a (USM/JPEM/15080267).

Rezultati

Prodor boje na rubnim dijelovima za svaki uzorak u svakoj skupini analiziran Kruskal-Wallisovim testom pokazao je da nema statistički značajne razlike među skupinama (p - vrijednost = 0,193).

Medijan s međukvartilnim rasponom za svaku skupinu već je naveden i nalazi se u tablici 2. Pokazuje da skupina everStick ima najveći medijan, a skupina Parapost Fiber White najmanji.

Dvosmjerna ANOVA korištena je za analizu postotka prodora boje između everSticka, Paraposta XP, Parapost Fiber Whitea te kontrolnih skupina. Kao što se vidi u tablici 3, nije bilo značajne razlike u aritmetičkim sredinama postotaka prodora boje među skupinama uz p-vrijednost = 0, 009 i F-statističku vrijednost od 4,194 sa stupnjem slobode od 3. Aritmetička sredina i standardna devijacija za svaku skupinu

methylene blue dye for 24 hours at room temperature (21) followed by rinsing with tap water to remove excess dye. All teeth were sectioned transversely from the tooth core interface towards the apex (Exact, Germany) and observed under 30x magnification stereomicroscope (Leica, Germany). Descriptive measurements were made from the photograph of the sectioned tooth followed by measuring the depth of dye penetration along the post preparation area in mm in order to obtain the sign and depth of the leakage. Ratios of dye penetration to entire section of the roots were measured and dye penetration percentages were recorded.

Statistical Analysis

Statistical Package for the IBM Social Sciences (SPSS) version 22.0 was used for data entry. Non parametric analysis using Kruskal-Wallis test was performed to determine and compare the mean depth of dye penetration between everStick, parapost XP, parapost fiber white and control groups while a two-way ANOVA was performed to determine and compare the percentage of dye penetration these groups. The mean score with significant P-value was tested using multiple comparison Post-hoc tests (Scheffe's procedure). The p-value was set as significant at $p<0.05$.

Ethical clearance

Ethical clearance was obtained from USM research and approval was obtained from the Ethics Committee (USM/JPEM/15080267).

Results

The dye penetration at the marginal area for each specimen in each group was analyzed using Kruskal-Wallis and the result showed there was no significance of the median between the groups (p-value =0.193). The median with interquartile range for each group was as stated in Table 2. It showed that everStick group had the highest median while Parapost fiber white group had the lowest median.

A two-way ANOVA was used to analyze the percentage of dye penetration between everStick, Parapost XP, Parapost fiber white, and control groups. As shown in Table 3, there was a significant difference of the mean of the percentage of dye penetration between the groups with p-value of = 0.009 and the F-statistic value was 4.194 with degree of freedom (df) 3. The mean and standard deviations for each group were as shown in Table 3. The highest mean was presented in the

Tablica 2. Usporedba medijana dubine prodora boje između everSticka, Paraposta XP, Parapost Fiber Whitea i kontrolnih skupina
Table 2 Comparison of median depth of dye penetration between everStick, Parapost XP, Parapost fiber white and control groups.

Skupina • Group	Prodor boje na rubu • Dye penetration at the margin (µm) Medijan • Median (IQR)	p-vrijednost [a] • p-value[a]
Parapost XP	1884.23 (1477.360)	0.193
Parapost Fiber White (PF160)	892.43 (1816.050)	
everStick	2018.01 (1746.130)	
Control	1919.14 (573.560)	

[a] Kruskal-Wallis test

Tablica 3. Usporedba srednje vrijednosti prodora boje između everSticka, Paraposta XP, Parapost Fiber Whitea i kontrolnih skupina
Table 3 Comparison of mean percentage of dye penetration between everStick, Parapost XP, Parapost fiber white and control groups.

Skupina • Group	Postotak prodora boje na rubu • Percentage of Dye Penetration at Margin Aritmetička sredina • Mean (SD)	F-stat (df)	p-vrijednost • p-value
Parapost XP	82.97 (48.793)	4.194 (3)	0.009 [a]
Parapost Fiber White (PF160)	49.87 (38.514)		
everStick	84.71 (28.310)		
Control	94.68 (19.173)		

[a] post-hoc pokazuje značajnu razliku između Fiber Whitea Paraposta i kontrolne skupine • post-hoc shows significant difference between Fiber White post and Control group.

nalaze se u tablici 3. Najviša srednja vrijednost dobivena je u kontrolnoj skupini, a Parapost Fiber White pokazao je najnižu aritmetičku sredinu.

Na temelju dobivenih rezultata, u dva uzorka u skupini everStick boja je prodrla do područja korijenskog kanala (60,63 % i 42,81 %). Bilo je prodora boje i među uzorcima u skupini Parapost XP (38,05 %), između dvaju uzoraka u skupini Parapost Fiber White (22,97 % i 27,41 %), te također u kontrolnoj skupini – 93,64 %. Svi uzorci u skupinama everStick i Parapost XP imali su prodor boje na rubnim dijelovima, a 15 od 17 uzoraka iz skupine Parapost Fiber White te 16 od 17 uzoraka iz kontrolne skupine pokazivalo je rubni prodor boje.

Rasprava

U ovom istraživanju nije bilo značajne razlike u dubini prodiranja boje između everSticka, Paraposta XP, Parapost Fiber Whitea i kontrolnih skupina. Ti rezultati mogu biti pod utjecajem zdrave strukture zuba od 2 mm koja je djelovala kao ferula za svaki uzorak, što je rezultiralo izostajanjem razlika. Predloženo je da ferula, kao dio kolčića i nadogradnje, omogući otpornost na funkcionalne sile i učinak klina kod koničnih kolčića (4). Pri prisutnosti barem 1,5 mm ferule u jednokorijenskim zubima ustanovljeno je da nastaje veća otpornost na neuspjeh. Ferula omogućuje manje opterećenje kolčića i nadogradnje vezujući cement i konačnu restauraciju (22). Taj nalaz sličan je istraživanju Libmana i Nichollsa (1995.) koji smatraju da je od 1,5 do 2 mm ferule omogućilo veću otpornost na neuspjeh.

Skupina everStick pokazala je najveći medijan dubine prodora boje u usporedbi s drugim skupinama u ovom istraživanju. Taj rezultat je možda pod utjecajem svojstava samog materijala everSticka. Naime, ljepljiv je u polimeriziranom stanju i vlakna imaju tendenciju razdvajanja (24). Ti čimbenici mogu uzrokovati kontaminaciju i promjenu materijala te tako spriječiti stvaranje monobloka s dentinom (25). Dodatni čimbenik koji pridonosi dubljem prodiranju boje u skupini everStick može biti i učinak skupljanja pri polimerizaciji. Budući da se everStick polimerizira nakon što se adaptira u korijenski kanal, polimerizacijska kontrakcija može stvoriti pukotinu između kolčića i dentinskog zida (11). To je u ovom istraživanju moglo uzrokovati odvajanje cementa nakon podvrgavanja postupnom opterećenju.

Torbjörner i suradnici (1996.) izvijestili su o degradaciji i hidrolizi te o degradaciji organskog matriksa kompozita po-

control group while Parapost Fiber White showed the lowest mean.

Based on the result obtained, there were two samples in everStick group where the penetration of the dye reached the canal area by 60.63% and 42.81%. There was also dye penetration in canal of a sample in Parapost XP group which was by 38.05%, two samples in Parapost Fiber Fhite group which were by 22.97% and 27.41%, and also a sample in the control group which was by 93.64%. All samples in everStick and Parapost XP groups were presented with dye penetration at the marginal area, whereas 15 out of 17 samples in Parapost Fiber White group and 16 out of 17 samples in the control group presented with marginal dye penetration.

Discussion

There were no significant differences in depth of dye penetration between everStick, Parapost XP, Parapost Fiber White, and control groups in this study. These results may be influenced by the presence of 2mm sound tooth structure that acted as a ferrule for each specimen, thus resulting in no difference in the outcome. It had been suggested that the presence of ferrule as part of post and core system would resist functional lever forces and the wedging effect of tapered post (4). The presence of at least 1.5mm ferrule in single rooted teeth was reported to have better resistance to failure. Ferrule provides less impact to the post and core system, luting cements and the final restorations (22). This finding was similar to a study by Libman and Nicholls (1995) where the presence of 1.5-2mm ferrules provides better resistance to failure.

The everStick group showed the highest median depth of dye penetration compared to other groups in this study. This result may be influenced by the properties of the everStick material itself. The material itself has sticky behavior in a polymerized state and the fibers have a tendency to separate [24]. These factors may cause contamination and alteration to the material itself that prevent the formation of a monoblock with the dentine (25). Another factor that leads to deeper leakage in the everStick group may also be the effect of polymerization shrinkage. As everStick was cured after it was adapted into the canal, polymerization shrinkage may have caused gap formation between the post and the dentinal wall (11). This may have caused the separation of cement when introduced to gradual loading in this study.

Torbjörner *et al.* (1996) reported that degradation and hydrolysis of the organic matrix occurred in fiber reinforced

jačanog vlaknima (FRC) kao o reakciji na utjecaj vlage i smolastog materijala u FRC materijalu. Sama reakcija potaknula je bubrenje matriksa i posljedično odvajanje adhezivne veze i/ili pucanje na površini vlakana. To povećava apsorpciju vode u FRC kolčićima i istodobno smanjuje njihova mehanička svojstva. Povećanje udjela vlakana u polimernoj matrici značajno povećava otpornost na frakturu, krtost i otpornost na zamor materijala kolčića (27). To može objasniti zašto je Parapost Fiber White post imao manje mikropropuštanja u usporedbi s kolčićima everSticka.

Savitljivost kolčića vrlo je važna u raspodjeli opterećenja i preživljavanju zuba restauriranog kolčićem i nadogradnjom. Naši rezultati ipak su u suprotnosti s onima iz istraživanja Lassila i suradnika (2004.) – njihovi rezultati testa trostrukog savijanja pokazali su da je everStick najčvršći u odnosu prema drugim FRC kolčićima koji su uključivali i Parapost Fiber White. Takvi rezultati mogu se pripisati razlici u polimernoj matrici everStick kolčića u kojoj nema lanaca polimetill-metakrilata (PMMA) koji mogu plastificirati križnu vezu s matriksom na temelju bisfenol-glicidil-metakrilata (bisGMA), što smanjuje napetosti na spoju vlakana i matriksa tijekom savijanja.

Ustanovili smo da Parapost XP ima manji obujam mikropropuštanja u usporedbi sa skupinom everStick, što je u suglasju s Reidom i suradnicima (2003.). Oni su izvijestili da je nemetalna skupina imala značajno povećanje u mikropropuštanju u usporedbi s metalnim skupinama zbog postupka termocikliranja. To se može dogoditi zbog degradacije polimera koji drži vlakna na okupu i/ili samih vlakana jer su podložna stresu tijekom termocikliranja (2). No nema dokaza o razlici pri usporedbi čvrstoće savijanja različitih vrsta kolčića i proizvođača.

Na temelju dvosmjerne analize ANOVA-e nije bilo značajne razlike u postotku prodora boje između skupina, a post-hoc test pokazao je značajnu razliku između Parapost Fiber Whitea i kontrolnih skupina. Rezultati su pokazali da je u skupinama u kojima su korišteni kolčić i nadogradnja prodori boje bili manji u usporedbi s onima u kojima su zubi restaurirani bez kolčića.

Da bi se pojačao endodontski liječen zub, koristi se sustav s kolčićem kako bi se stabilizirala i ojačala restauracija na preostalom dijelu zubne strukture (29). Dakle, može se zaključiti da endodontski liječeni zubi bez postavljanja kolčića imaju manje stabilnu nadogradnju i istodobno povećavaju obujam mikropropuštanja u zub.

Ovo istraživanje provedeno je uz postupno opterećenje, kao alternativa cikličkom opterećenju. Cikličko opterećenje uzrokuje savijanje kolčića i odvajanje adhezivnog sloja između zubne strukture i kolčića i/ili nadogradnje (3), što objašnjava zašto je u neke naše uzorke u svakoj skupini boja prodrla do korijenskog kanala. Na temelju istraživanja Naumanna i suradnika (2005.), postupno opterećenje daje klinički relevantne informacije. Postupno opterećenje koje je korišteno u ovom istraživanju jest modifikacija modela testiranja koji je prikazan kao simulacija žvakanja i linearnog kompresivnog opterećenja. Ta prilagodba omogućila nam je da obavimo testiranje materijala na endodontski liječenim zubima uz uštedu vremena i novca. Linearno kompresivno opterećenje

composite (FRC) post as a reaction to the contact between moisture and resin based material in the FRC itself. The reaction caused the matrix to swell, which later resulted in debonding and/or cracking of the fiber interface. This will increase the water absorption by the FRC post and simultaneously decrease their mechanical properties. An increase in fibers to a polymer matrix will significantly increase the fracture toughness, stiffness and fatigue resistance of the post (27). This statement may explain the reason why Parapost Fiber White post had lower microleakage compared to an everStick post.

Flexural properties of a post play a major role in stress distribution and survival of a post-restored tooth. Our finding was however contradicted with a study by Lassila *et al.* (2004) where the result from the three-point bending test unexpectedly showed that everStick had the highest flexural strength compared to other tested FRC posts which include Parapost fiber white. This may occur due to the difference in polymer matrix of everStick post where there is existence of polymethyl methacrylate (PMMA) chains which have the ability to plasticize the cross-linked Bisphenol A Glycidyl Methacrylate (bisGMA) based matrix which reduces stress formation at the fiber-matrix-interface during deflection.

We found that Parapost XP had lower microleakage pattern compared to everStick group, which is similar to the finding by Reid *et al.* (2003). They reported that a nonmetallic group had significant increase in microleakage compared to the metallic groups due to thermocycling process. This might be due to degradation of the polymer that hold the fibers together and/or the fibers themselves were susceptible to stress during thermocycling (2). However, there was no evidence found regarding flexural strength specifically comparisons between the post types and brands.

Based on the two-way ANOVA analysis, there was a significant difference in percentage of dye penetration between the groups where the post-hoc test showed a significant difference between Parapost Fiber White and control groups. The result showed that the group treated with post and core had lower dye penetration within the group compared to the control group that had not been restored with post. In order to reinforce an endodontically treated tooth, post system is used to provide stabilization and fasten the restoration to the remaining tooth structure (29). Thus, it can be concluded that endodontically treated teeth without post placement causes the core to be less stable and at the same time increases the microleakage of the teeth.

This study was performed under gradual loading as an alternative to cyclic loading. Cyclic loading caused flexion to posts and resulted in adhesive failure between the tooth structure and the post and/or the core (3), which explained why some of our samples in each group had dye penetration that reached the canal. Based on study by Naumann *et al.* (2005), gradual loading test was able to provide the information that was clinically relevant. The gradual loading used in this study is a modification of a testing model previously introduced which was chewing simulation and linear compressive loading. This modification allowed us to do material testing procedure for endodontically treated teeth in a time-

je nepovoljnije za testiranje kolčića i nadogradnji jer može rezultirati nejednakim kapacitetom opterećenja koje se ne pojavljuje u dinamičkim metodama. Iz tih razloga je, prema preporukama, u ovom istraživanju korišteno postupno opterećenje.

Premda postupno opterećenje može dati klinički relevantne rezultate, bilo bi točnije kad bi se testiranje materijala obavilo pod simulacijom žvakanja, jer bi se tada bolje mogla oponašati stvarna raspodjela okluzalnih sila.

Zaključak

Nije bilo značajne razlike u mikropropuštanju između everSticka, Paraposta XP, Parapost Fiber Whitea i kontrolnih skupina. Postotak marginalnog prodora boje bio je značajan između Parapost Fiber Whitea i kontrolnih skupina.

Sukob interesa

Autori nisu bili u sukobu interesa.

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saving and inexpensive manner. Linear compressive loading is less favorable for post materials testing since it may result in unequal load capacities not appearing in either dynamic method. Thus, gradual loading had been used following the recommendation by the study.

Although gradual loading could produce results that are clinically relevant, it would be more accurate if the material testing could be done under chewing simulation in which it will be able to mimic the real occlusal forces distribution.

Conclusion

There was no difference in microleakage between everStick, Parapost XP, Parapost fiber white and control groups. The percentage of marginal dye penetration was significant between Parapost fiber white and the control groups.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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Abstract

Objective: This study aimed to compare the difference in marginal dye penetration between everStick, Parapost XP, Parapost fiber white and control groups under gradual loading. **Materials and Methods:** Sixty-eight human maxillary permanent incisors were divided into four groups. Each specimen was endodontically treated with step-back technique and prepared for each post system according to experimental groups, subsequently cemented in the canal. Composite resin cores were built and laboratory fabricated metal crowns were cemented. All specimens except those in the control group were subjected to thermal cycling. All groups were subjected to gradual loading from 0N-50N for 100 cycles. Specimens were sectioned transversely and the depths of dye penetration along the post were measured. Data were entered in SPSS ver. 22 and analyzed using two-way ANOVA test. **Results:** There was no significant difference in marginal dye penetration between each group (p-value>0.05). However, there was a significant difference in percentage of marginal dye penetration between all groups (p-value<0.05); post-hoc comparison showed significant difference between Fiber White and Control groups (p-value=0.009). **Conclusion:** All the groups showed dye penetration but the percentage was significant only between Parapost Fiber White and the control groups.

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Endodontics; Post and Core Technique; Fiber Reinforced Polymers; Dental Marginal Adaptation; Dental Leakage

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