ACTA
STOMATOLOGICA
CROATICA
www.ascro.hr

Acta stomatol Croat. 2016;50(4):321-328.
DOI: 10.15644/asc50/4/5

IZVORNI ZNANSTVENI RAD
ORIGINAL SCIENTIFIC PAPER

Ivana Parčina Amižić[1], Ivana Miletić[2], Andrei C. Ionescu[3], Eugenio Brambilla[3], Dragana Gabrić[4], Anja Baraba[2]

Utjecaj ispiranja aktiviranog erbijskim laserima na čvrstoću vezivanja individualnog kompozitnog kolčića ojačanog vlaknima na dentin korijenskog kanala

Influence of Laser Activated Irrigation with Erbium Lasers on Bond Strength of Inidividually Formed Fiber Reinforced Composite Posts to Root Canal Dentin

[1] Odjel dentalne medicine Doma zdravlja Splitsko-dalmatinske županije, Split, Hrvatska
Department of Dental Medicine, Health Center for County of Dalmatia, Split, Croatia
[2] Zavod za endodonciju i restaurativnu stomatologiju Stomatološkog fakulteta Sveučilišta u Zagrebu, Zagreb, Hrvatska
Department of Endodontics and Restorative Dentistry, School of Dental Medicine, University of Zagreb, Zagreb, Croatia
[3] Odjel za biomedicinu, kirurgiju i stomatologiju Instituta Galeazzi Sveučilišta u Milanu, Milano, Italija
Department of Biomedical, Surgical and Dental Sciences, Galeazzi Institute, University of Milan, Milan, Italy
[4] Zavod za oralnu kirurgiju Stomatološkog fakulteta Sveučilišta u Zagrebu, Zagreb, Hrvatska
Department of Oral Surgery, School of Dental Medicine, University of Zagreb, Zagreb, Croatia

Sažetak

Svrha: Željelo se *in vitro* istražiti učinak ispiranja aktiviranog različitim erbijskim laserima na čvrstoću vezivanja individualnog kolčića ojačanog vlaknima na dentin korijenskog kanala. **Materijali i metode:** Dvadeset i sedam jednokorijenskih zuba endodontski su tretirani i poslije preparacije za postavljanje intrakanalnog kolčića podijeljeni u tri skupine (n = 9 po skupini), ovisno o vrsti predtretmana korijenskog dentina: 1. skupina – konvencionalno ispiranje fiziološkom otopinom (kontrolna skupina); 2. skupina – ispiranje fiziološkom otopinom i aktivacija PIPS nastavkom lasera Er:YAG; 3. skupina – ispiranje i aktivacija RFT2 nastavkom lasera Er,Cr:YSGG. Dva uzorka iz svake skupine upotrijebljena su za SEM analizu. U preostale je (n = 7 po skupini) cementiran individualni kolčić ojačan vlaknima *everStick POST* – korišten je samoadhezivni cement *G-CEM LinkAce*. Nakon cementiranja uzorci su prerezani okomito na uzdužnu os na nove jedan milimetar debele uzorke koji su podvrgnuti *push-out* testiranju (0,5 mm/min.). Rezultati su zabilježeni u MPa-u, a logaritmirani i statistički analizirani su ANOVA testom na razini značajnosti od 5 posto. **Rezultati:** U kontrolnoj skupini zaostatni sloj bio je još prisutan, u skupni Er:YAG bio je uklonjen, a u skupini Er,Cr:YSGG bio je djelomično uklonjen. U skupini Er,Cr:YSGG postignute su najviše vrijednosti čvrstoće vezivanja, slijedila je kontrolna skupina i tek tada skupina Er:YAG. Ipak, među vrijednostima čvrstoće vezivanja spomenutih skupina nije pronađena statistički značajna razlika (p = 0,564). **Zaključak:** Ispiranje aktivirano nastavcima erbijskih lasera PIPS i RFT2 nije utjecalo na čvrstoću vezivanja individualnih kolčića ojačanih vlaknima na dentin korijenskog kanala.

Zaprimljen: 25. listopada 2016.
Prihvaćen: 1. prosinca 2016.

Adresa za dopisivanje
Ivana Parčina Amižić
Dom zdravlja SDŽ
Odjel dentalne medicine
Matoševa 2, 21 000 Split, Croatia
tel: +385 21 384 569
ivana.parcina@st.t-com.hr

Ključne riječi
tehnika kolčića i nadogradnje; solid-state laseri; priprema korijenskog kanala; staklenim vlaknima ojačani polimeri

Uvod

Vlaknima ojačani kolčići uobičajeno se koriste za postendodontske restauracije, uglavnom zbog njihovih povoljnih fizikalnih svojstava tj. modula elastičnosti sličnog dentinskome (1). Ipak, klinički neuspjesi koji se odnose na endodontski tretirane zube restaurirane kolčićima ojačanima vlaknima mogu se dogoditi, a uzrok je uglavnom odvajanje cementa (2). Upravo oblik i sastav različitih kolčića ojačanih vlaknima može utjecati na svojstvo vezivanja samog kolčića, a time i na kvalitetu restauracije (3). Konfekcijski kolčići ojačani vlaknima imaju visoko umreženu polimernu matricu s visokim stupnjem konverzije, a to otežava njihovo vezivanje na kompozitni cement i zubnu strukturu (4).

Introduction

Fiber reinforced composite (FRC) posts are commonly used by clinicians in post-endodontic restorations, mostly due to their favorable physical properties, i.e. the modulus of elasticity close to that of dentin (1). Yet, clinical failures involving endodontically treated teeth reconstructed with FRC posts could occur and are mainly attributed to cementation flaws (2). The design and composition of different FRC posts may affect their bonding capacity and restoration quality (3). Prefabricated FRC posts exhibit a highly cross-linked polymer matrix with high degree of conversion, which makes it difficult to bond the post to composite resin cement and tooth structure (4).

Prije nekoliko godina predstavljen je nov način vezivanja između kolčića ojačanog vlaknima i smolastog materijala koji se temelji na interpenetrirajućoj polimernoj mreži (engl. interpenetrating polymer network – IPN) (5). Polimerna matrica individualnog kolčića ojačanog vlaknima sastoji se i od linearne i od umrežene faze koje formiraju poluinterpenetrirajuću polimernu mrežu (engl. semi-IPN). Osim toga, individualni kolčić ojačan staklenim vlaknima fleksibilan je i nepolimeriziran, te zbog toga može biti polimeriziran *in situ* u korijenskom kanalu, čime se omogućuje slobodna radikalska polimerizacija između kolčića i kompozitnog cementa (6).

Vrsta irigacijskog protokola, nakon prepariranja mjesta za postavljanje kolčića i prije cementiranja, također može utjecati na kvalitetu vezivanja kolčića ojačanih vlaknima na dentin (7). Razmjeno novi pristupi u predtretmanu korijenskog dentina, tj. u uklanjanju zaostatnog sloja, uključuju uporabu lasera Er:YAG ili Er,Cr:YSGG u postupku nazvanom *ispiranje aktivirano laserom* (engl. laser activated irrigation – LAI) koji se temelji na prolaznoj kavitaciji i akustičnom prijenosu u intrakanalnim tekućinama (8). U slučaju kada se jedini komercijalno dostupan dentalni laser Er,Cr:YSGG Waterlase (Biolase, Irvine CA, SAD) koristi s radijalnim nastavkom poput RFT2 i postavkama laserskih parametara od 1,25 W, 50 Hz, 24 posto zraka, 30 posto vode, tada se uklanjanje zaostatnog sloja i naslaga može obaviti bez uporabe kemijskih irigansa. Taj proces naziva se hidrofotonika, a stvara strujanje vode i snažan mikroagitacijski učinak u cijelom korijenskom kanalu (9). S druge strane, fotoakustično strujanje potaknuto fotonima (engl. Photon Induced Photoacustic Streaming – PIPS) posebna je tehnika LAI koja pretpostavlja uporabu lasera Er:YAG LightWalker AT (Fotona, Ljubljana, Slovenija) i novooblikovanog radijalnog nastavka za uklanjanje bakterija i zaostatnog sloja u korijenskom kanalu (10, 11). Nastavak PIPS koristi se pri minimalno ablativnim energijskim razinama od 20 mJ i 15 Hz, s trajanjem impulsa od 50 μs i stvara samo fotoakustični i fotomehanički učinak (12). Svaki impuls djeluje na vodene molekule stvarajući fenomen udarnog vala pri čemu nastaje snažno strujanje tekućina, čak i u dijelovima udaljenima od izvora (13).

S obzirom na nedostatak odgovarajuće literature, cilj ovog istraživanja *in vitro* bio je istražiti učinak dviju tehnika ispiranja aktiviranih laserima na čvrstoću vezivanja individualnih kolčića ojačanih vlaknima na dentin korijenskoga kanala. Nulta hipoteza bila je da ispiranje aktivirano različitim erbijskim laserima ne utječe na čvrstoću vezivanja individualnih kolčića ojačanih vlaknima na dentin korijenskoga kanala.

Materijali i metode

Istraživanje je odobrio Etički odbor Stomatološkog fakulteta Sveučilišta u Zagrebu. Za provedbu istraživanja odabrano je dvadeset i sedam (n = 27) izvađenih jednokorijenskih humanih premolara sličnih dimenzija i ravnog korijena, bez endodontskih tretmana i intrakanalnih kolčića. Zubi su očišćeni kiretama i do početka istraživanja bili su pohranjeni u fiziološkoj otopini. U svrhu istraživanja svim je zubima ispod caklinsko-cementnoga spojišta dijamantnim svrdlom uklonjena kruna, uz vodeno hlađenje. Korijenski kanali obrađe-

Several years ago, an interpenetrating polymer network (IPN) bonding between a FRC post and resin was presented and it was based on the interdiffusion of monomer into the polym,er substrate (5). The polymer matrix of an individually formed FRC post consists of both linear polymer and cross-linked polymer phases, which is called semi-IPN. An individually formed FRC post is flexible and unpolymerized glass fiber post that can be polymerized *in situ* in the root canal, which enables free radical polymerization to occur between the resin matrix of the post and the composite resin luting cement (6).

The type of irrigation protocol, after post space preparation and before post cementation, may also affect the bonding quality of FRC posts to dentin (7). Relatively new approaches to pretreatment of radicular dentin, i.e. removing smear layer, include the use of Er:YAG or Er,Cr:YSGG laser in a procedure known as laser activated irrigation (LAI), that is based on the production of transient cavitation and acoustic streaming in intracanal fluids (8). If the only commercially available Er,Cr:YSGG dental laser Waterlase (Biolase, Irvine CA, USA) is used with radial-firing tips like the RFT2 and laser parameters as follows: 1.25 W, 50 Hz, 24% air, 30% water, then the removal of the smear layer and debris can be performed without using chemical irrigants. This process is called Hydrophotonics and it creates water movement and a powerful micro-agitation effect throughout the whole root canal system (9). On the other hand, the photon-induced photoacoustic streaming (PIPS) is a specific LAI technique that presupposes the use of Er:YAG LightWalker AT (Fotona, Ljubljana, Slovenia) and a newly designed radial and stripped tip for removing bacteria and smear layer in root canals (10,11). The PIPS tip is used at minimally ablative energy levels of 20 mJ at 15 Hz, with impulses of only 50 μs, generating only photoacoustic and photomechanical effect (12). Each impulse interacts with water molecules, creating a shock wave-like phenomenon leading to the formation of powerful streaming of fluids distant from the source (13).

Since there is a lack of sufficient data, the aim of this *in vitro* study was to investigate the effect of two LAI techniques on bond strength of an individually formed FRC post to root canal dentin. The null hypothesis was that the LAI, using two different erbium lasers, does not affect the bond strength of individually formed FRC posts to root canal dentin.

Materials and methods

The study protocol was reviewed and approved by the Ethics Commitee of the School of Dental Medicine, University of Zagreb. Twenty-seven (n=27) extracted single-rooted human premolars with similar size and straight root, without previous endodontic treatments and posts, were selected for the study. The extraneous tissue and calculus were removed using curettes and the teeth were stored in saline prior to instrumentation. The crown of each tooth was sectioned below the cemento-enamel junction with a diamond bur at high ni su instrumentima Reciproc do veličine od R40 (VDW, München, Njemačka), poštujući pritom upute proizvođača. Jednominutno završno ispiranje obavljeno i je s 2 ml 17-postotne EDTA-e (pH = 7,7), nakon čega je slijedilo ispiranje fiziološkom otopinom. Obrađeni korijenski kanali posušeni su papirnatim štapićima Reciproc veličine #40 (VDW, München, Njemačka) te napunjeni odgovarajućim štapićem gutaperke Reciproc #40 (VDW, München, Njemačka) i punilom AH Plus (Dentsply Maillefer, Ballaigues, Švicarska). Višak gutaperke uklonjen je zagrijanim nabijačem 1 mm od caklinsko-cementnog spojišta. Uzorci su zatim pohranjeni na 37 °C tjedan dana do potpunog stvrdnjavanja punjenja.

Nakon tjedan dana mjesto za kolčić preparirano je Gates-Gliddenovim svrdlom #4 ostavljajući 5 mm gutaperke u apikalnom dijelu.. Dubina preparacije mjerena je endodontski ručnim instrumentom – proširivačem veličine #40. Nakon završene preparacije uzorci su nasumično podijeljeni u tri skupine (n = 9), ovisno o postupku obrade korijenskog kanala:

1. skupina – konvencionalno ispiranje fiziološkom otopinom (kontrola)
2. skupina – laser Er:YAG s PIPS nastavkom
3. skupina – laser Er, Cr:YSGG s RFT2 nastavkom

U prvoj su skupini korijenski kanali uzoraka isprani s 5ml fiziološke otopine (Braun Melsungen AG, Melsungen, Njemačka), koristeći se punom jednokratnom štrcaljkom od 2 ml (Braun Melsungen AG, Melsungen, Njemačka) i iglom od 27-G (BD Microlane 3;BD, Drogheda, Irska), nakon čega su posušeni papirnatim štapićima Reciproc veličine #40.

U drugoj skupini upotrijebljen je laser Er:YAG (Fidelis, Fotona, Ljubljana, Slovenija) s 14-mm dugim PIPS nastavkom promjera 400 µm tijekom 40 sekunda, uz neprestano uštrcavanje 2 ml fiziološke otopine jednokratnom štrcaljkom od 2 ml i iglom veličine 27-G. Laserski nastavak mirovao je u koronarnom dijelu kanala i nije napredovao dublje u korijenski kanal. Postavke parametara pulsa bile su sljedeće: 20 mJ, 15 Hz i 50 µs.

U trećoj skupini upotrijebljen je laser Er, Cr:YSGG (Waterlase, Biolase, Irvine CA, SAD) s 25-mm dugim RFT2 nastavkom promjera 275 µm. Laserski nastavak unesen je u korijenski kanal na udaljenost od 1 mm od gutaperke nakon čega je laser aktiviran, a nastavak kružnom kretnjom, uz dodirivanje dentinskih zidova i brzinom od 1mm/s, izvučen iz korijenskog kanala. Parametri lasera bili su postavljeni na sljedeće vrijednosti: 1,25 W, 50 Hz, 24 posto zraka i 30 posto vode (demineralizirane). Taj postupak ponovljen je tri puta za svaki uzorak.

U obje laserske skupine završno ispiranje obavljeno je s 5 ml fiziološke otopine, nakon čega su uzorci posušeni odgovarajućim papirnatim štapićima Reciproc veličine #40.

Dva uzorka (n = 2) iz svake skupine upotrijebljena su za SEM analizu kako bi se potvrdio izgled površine dentina u korijenskom kanalu nakon tri različita predtretmana mjesta za postavljanje kolčića.

U preostale uzorke u svakoj skupini (n = 7) postavljen je individualni kolčić ojačan vlaknima *everStick POST* (GC, Tokio, Japan) promjera 1,2 mm. Prije cementiranja svaki je skraćen na željenu duljinu univerzalnim škaricama i podešen pincetom u korijenskom kanalu. Nakon toga kolčić

speed under copious water-cooling. The root canals were instrumented with rotary Reciproc instruments up to size R40 (VDW, Munich, Germany), according to the instructions of the manufacturer. A final flush with 2ml of 17% EDTA (pH=7.7) for 1 min followed by saline was used to irrigate the root canal. The canals were dried using Reciproc paper points size R40 (VDW, Munich, Germany) and obturated with Reciproc guttapercha cone size R40 (VDW, Munich, Germany) and AH plus sealer (DeTrey Dentsply, Konstanz, Germany). Excess gutta-percha was removed with hot pluggers 1 mm from the cemento-enamel junction. All specimens were stored at 37°C for 1 week for complete setting.

After 1 week, the gutta-percha was removed using # 4 Gates Glidden burs, leaving 5 mm of the apical seal. The depth of the prepared canal was measured with a hand instrument size #40 K-file). After post-space preparation, all specimens (n=27) were subdivided into three groups (n=9), according to the type of intraradicular dentin treatments:

1. Conventional syringe irrigation (CSI) and saline (control group);
2. Er:YAG laser with PIPS tip;
3. Er,Cr:YSGG laser with RFT2 tip.

In the first group (control group), the prepared post spaces were rinsed using 5 ml of saline (Braun Melsungen AG, Melsungen, Germany) in 2 ml disposable syringe (Braun Melsungen AG, Melsungen, Germany) and a 27-G needle (BD Microlane 3; BD, Drogheda, Ireland) for each specimen. Excess moisture was removed with suitable Reciproc paper points (size R40).

In the second group, after post-space preparation , Er:YAG laser (Fidelis, Fotona, Ljubljana, Slovenia) with a 14-mm long and 400 micron diameter tapered PIPS tip was used for 40 s with 2 ml of saline in a disposable syringe and a 27-gauge needle positioned above the laser tip, in the coronal aspect of the root canal. The laser tip was kept stationary and did not advance into the canal. The laser operating parameters were as follows: 20 mJ per pulse, 15 Hz, and 50 µs pulse duration.

In the third group, Er, Cr:YSGG laser (Waterlase, Biolase, Irvine CA, USA) was used with 25 mm long RFT2 tip. RFT2 tip, 275 micron in diameter, was inserted 1 mm short of the length of the preparation, laser was activated on withdrawal of the tip coronally at approximately 1mm/s and the tip was maintained in contact with the side surface of the canal wall during the entire apical to coronal pass. The laser parameters used were: 1.25 W, 50 Hz, 24% air and 30% water (demineralized). The same procedure was repeated three times to ensure an adequate cleaning of the post-space preparation.

In both laser groups, the post-space preparations were rinsed using 5 ml of saline for each specimen and dried with suitable Reciproc paper points (size R40).

Two specimens (n=2) from each group were used for SEM analysis in order to examine the appearance of the root canal dentin surface after three different pretreatments of post- space preparation.

The rest of the specimens in each group (n=7) received an individually formed FRC post, everStick POST, diameter 1.2

je izvađen i zaštićen od svjetla stavljanjem pod zaštitni poklopac.

Za cementiranje kolčića, na dvostruku štrcaljku G-Cem LinkAce (GC, Tokio, Japan) cementa postavljen je odgovarajući nastavak kojim je materijal istisnut u korijenski kanal nakon čega je postavljen kolčić. Umjerenim pritiskom kolčić je pridržavan i osvijetljen – svaka površina po 20 sekunda – LED polimerizacijskom svjetiljkom Bluephase (Ivoclar Vivadent, Schaan, Lihtenštajn) koristeći se programom niske snage (engl. *low power*) intenziteta 650 mW/cm.

Svi uzorci uloženi su u akrilatnu smolu (Orthocryl, Dentaurum, Ispringen, Njemačka). Isomet pilom 1000 (Buehler, Düsseldorf, Njemačka) prerezani su okomito na uzdužnu os na nove uzorke debljine 1 mm brzinom od 300 okretaja/min., uz vodeno hlađenje. Debljina svakog uzorka, te njegov veći i manji radijus, izmjereni su digitalnom mjerkom (Roc International Industry Co., Ltd., Guangdong, Kina), a vrijednosti zabilježene. Površina vezivanja izračunata je prema matematičkoj formuli gdje je π konstanta 3,14; R1 veći radijus; R2 manji radijus i h debljina. Korištena je formula krnjeg stošca:

Površina = $\pi (R1 + R2)\sqrt{(R1 - R2)^2 + h^2}$.

Svaki novi uzorak podvrgnut je *push-out* testu, a pritom se koristio univerzalni uređaj za testiranje (double-column 3300 series, Instron, Illinois, SAD) s nastavkom brzine 0,5 mm/min. i primijenjenim kompresivnim opterećenjem koje je trajalo sve do loma, tj. do popuštanja kolčića. Čvrstoća vezivanja izražena je u MPa-u, a dobivena je matematičkom operacijom dijeljenja opterećenja pri pucanju (N) s površinom vezivanja (mm^2).

Statistička analiza obavljena je u programskom paketu SAS System (v. 8.02, SAS Institute, SAD) za Windows operativni sustav. Podatci su logaritmirani i statistički analizirani testom ANOVA-e. Razina značajnosti postavljena je na 5 posto.

Rezultati

Push-out čvrstoća vezivanja

Ukupno je pripremljeno 58 uzoraka za *push-out* testiranje. Ni jedan nije podbacio ni tijekom pripreme ni tijekom testiranja. Originalne vrijednosti čvrstoće vezivanja (aritmetička sredina i standardna devijacija, MPa) pojedinih predtretmana dentina nalaze su u tablici 1. U skupini Er,Cr:YSGG zabilježene su najviše vrijednosti čvrstoće vezivanja, nakon čega je slijedila kontrolna skupina i na kraju skupina Er:YAG. ANOVA je na logaritmiranim podatcima pokazala da razlike među testiranim skupinama predtretmana dentina nisu bile statistički značajne (p = 0,564).

mm (GC, Tokyo, Japan). Each post was cut to premeasured length using scissors and fitted into the root canal using tweezers. The post was then removed from the canal and protected from light before cementing by placing it under a light shield.

For post cementation, the automix tip was attached to the syringe of self-adhesive cement G-Cem LinkAce (GC, Tokyo, Japan). The material was extruded into the post- space and the post was inserted with light hand pressure. Light activation was performed using LED polymerization lamp Bluephase (Ivoclar Vivadent, Schaan, Liechtenstein) at low-power intensity of 650mW/cm^2 and each surface was light cured for 20 seconds.

All the roots were embedded into acrylic resin (Orthocryl, Dentaurum, Ispringen, Germany) cut perpendicularly to the longitudinal axis with specimen thickness of 1 mm each, using an Isomet saw 1000 (Buehler, Dusseldorf, Germany) at a speed of 300 rpm under water cooling. The thickness of each sample was measured using digital caliper (Roc International Industry Co., Ltd., Guangdong, China). The bond area was calculated according to the formula where π is constant of 3.14; R1 larger radius; R2 smaller radius; and h is the thickness. A formula of a truncated cone was used as shown:

Area = $\pi (R1 + R2) \sqrt{(R1 - R2)^2 + h^2}$.

Each slice was subjected to a push-out test using a universal loading device (double-column 3300 series, Instron, Illinois, USA) at a crosshead speed of 0.5 mm/min with applied compressive load until the post was dislodged. The bond strength was calculated in MPa, dividing the failure load (N) by the bonding surface area (mm^2).

A statistical analysis was performed using the statistical package SAS system (v. 8.02, SAS Institute Inc., SAD) for Windows platform. The data were log-transformed and statistically analyzed using one-way ANOVA. The level of statistical significance was set at 5 %.

Results

Micro push-out bond strength

A total of 58 slices were prepared for push-out testing. None of the prepared specimens failed prematurely. The original bond strength values (mean and standard deviations) of dentin pretreatments are shown in Table 1. The Er,Cr:YSGG group achieved the highest bond strength values, followed by the control group and then the Er:YAG group. ANOVA on log-transformed data showed that differences among tested group of post-space pretreatment were not significant (p=0.564).

Tablica 1. Srednje vrijednosti *push-out* čvrstoće vezivanja (MPa) i standardne devijacije za ispitane načine predtretmana dentina (originalne vrijednosti)
Table 1 Mean push-out bond strength (MPa) and standard deviations for studied types of dentin pre-treatment (original values)

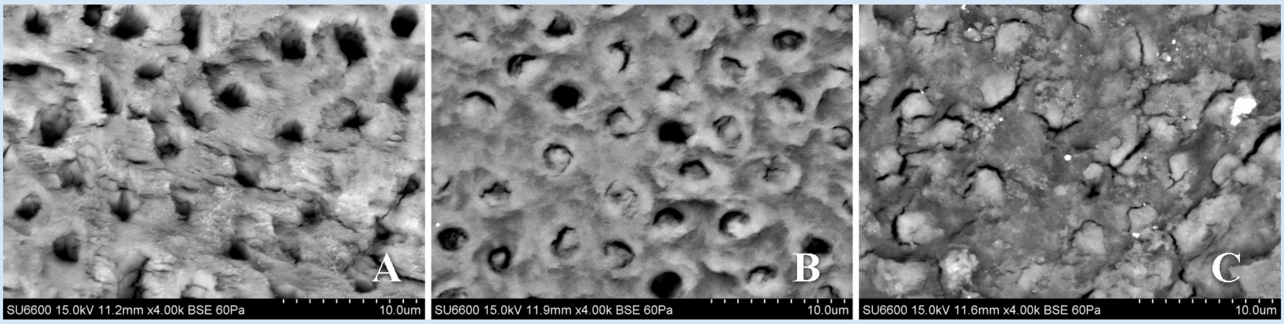
Predtretman dentina • Dentin pre-treatment	N	Arit. sred. ± StD (MP-a, originalne vrijednosti) • Mean ± StD (MPa,original values)
Fiziološka otopina (kontrola) • Saline (control)	19	4.43 ± 2.95
Er:YAG	20	3.90 ± 2.05
Er,Cr:YSGG	19	4.86 ± 3.27
Ukupno • Total	**58**	

SEM analiza

SEM analizom potvrđeno je da je u kontrolnoj skupini površina dentina bila prekrivena zaostatnim slojem i da su dentinski tubuli bili zatvoreni (slika 1. c). U skupini Er,Cr:YSGG dio dentinskih tubula bio je otvoren, a dio zatvoren, zaostatni sloj bio je mjestimičan, iako u tanjem sloju u usporedbi s kontrolnom skupinom (slika 1. b). U skupini Er:YAG površina dentina bila je čista, zaostatni sloj većinom je bio uklonjen, a dentinski tubuli otvoreni (slika 1. a).

SEM analysis

SEM analysis confirmed that dentinal tubules were occluded and the smear layer was still present in the control group (Figure 1C). In the Er,Cr:YSGG group, the dentinal tubules were partially opened and the smear layer was partially present but it was thinner compared to the control group (Figure 1B). In the Er:YAG group, dentin surfaces were clean, little residual smear layer was present and open dentinal tubules were observed (Figure 1A).



Slika 1. SEM fotografije površine dentina korijenskog kanala nakon tri različita predtretmana mjesta za kolčić – povećanje x 4000: (**A**) u skupini Er:YAG površina dentina bila je čista, dentinski tubuli bili su otvoreni i zaostatni sloj bio je većinom uklonjen; (**B**) u skupini Er,Cr:YSGG dio zaostatnog sloja bio je uklonjen s dentinskim tubulima dijelom otvorenima i dijelom začepljenima zaostatnim slojem; (**C**) u kontrolnoj skupini površina dentina bila je pokrivena zaostatnim slojem i dentinski tubuli bili su začepljeni

Figure 1 SEM images of the root dentin surface after three different pre-treatments of post space preparation, at x4000 magnification: (**A**) in the Er:YAG group, dentin surfaces were clean, dentinal tubules were opened and the smear layer was mostly removed; (**B**) in the Er,Cr:YSGG group, part of the smear layer was removed with some dentinal tubules opened and some still covered with smear plugs; (**C**) in the Saline solution (control) group, root canal dentin surfaces were coated with a smear layer and dentinal tubules were occluded.

Rasprava

Na temelju rezultata ovog istraživanja nulta hipoteza ne može biti odbačena. Obje ispitane tehnike ispiranja aktiviranog laserima nisu značajno utjecale na vrijednosti čvrstoće vezivanja individualnih kolčića ojačanih vlaknima na dentin korijenskoga kanala.

U istraživanju je čvrstoća vezivanja ispitana *push-out* modelom koji se pokazao najtočnijim i najpouzdanijim načinom za ocjenjivanje vezivanja kolčića ojačanih vlaknima na dentin korijenskog kanala u usporedbi s konvencionalnim i modificiranim mikrovlačnim testovima (14).

Već je prije pokazano da oblik kolčića ojačanog vlaknima može utjecati na čvrstoću vezivanja (15). U slučaju kada se kompozitni cement vezuje na kolčić ojačan vlaknima s poluinterpenetrirajućom polimernom mrežom, interdifuzijsko vezivanje može se ostvariti (15). Dodatno, volumen vlakana u koronarnom dijelu korijenskog kanala velik je i ispunjava cijeli slobodni prostor kanala pa zato povećava čvrstoću kolčića te stvara jaku potporu za krunsku nadogradnju (6).

Svojstva materijala za cementiranje također mogu utjecati na kvalitetu vezivanja kolčića ojačanih vlaknima na dentin korijenskog kanala (16). U istraživanju je za cementiranje kolčića upotrijebljen samoadhezivni cement zbog već prije potvrđenih visokih vrijednosti *push-out* čvrstoće vezivanja i niskih vrijednosti polimerizacijskog stresa (16).

Da bi se poboljšalo vezivanje kolčića ojačanog vlaknima i cementa na dentin korijenskog kanala, mogu se upotrijebiti različiti irigacijski protokoli za korijenski kanal. Ipak, proi-

Discussion

Based on the results of the present study, the null hypothesis could not be rejected. Both investigated LAI techniques did not significantly affect the bond strength values of individually formed FRC post to root canal dentin.

In the present study, bond strength was investigated using push-out model that was reported to be the most accurate and reliable technique to measure the bonding of FRC posts to root canal dentin compared with conventional and modified microtensile tests (14).

It has already been shown that push-out bond strength could be affected by the FRC post design (15). When the FRC post with the semi-IPN polymer matrix is bonded with composite resin luting cement, the interdiffusion bonding can take place (15). Additionally, fiber volume at the coronal part of the root canal is high and it fills the entire available root canal space and therefore increases the strength of the post and forms a strong support for the core (6).

The properties of luting materials may also be effective on the bonding quality of FRC post to root canal dentin (16). In the present study, for cementing post, a self-adhesive cement was chosen because of previously reported high push-out bond strength values and lower polymerization stress (16).

Various final root canal irrigation protocols can be used to enhance the bonding of FRC posts and cements to root canal dentin. However, the manufacturer of the self-adhesive cement has warned that the use of EDTA (ethylenediaminetetraacetic acid) or H_2O_2 (hydrogen peroxide) could decrease zvođač samoadhezivnog cementa upozorava da uporaba EDTA-e (etilendiamintetraoctene kiseline) ili H_2O_2 (vodikova peroksida) može smanjiti čvrstoću vezivanja materijala. Calt i Serper istaknuli su 2002. godine (17) da uporaba EDTA-e dulje od 1 minute može erodirati i oštetiti korijenski dentin. U dvije studije istaknuta je nekompatibilnost između CHX-a (klorheksidina) (18) te NaOCl-a (natrijeva hipoklorita) (19) i samoadhezivnog cementa. Pokušavajući izbjeći neželjene promjene u korijenskom dentinu, istraživači su se odnedavno usmjerili na uklanjanje zaostatnog sloja laserskom iradijacijom. No ustanovili su da i laserska zraka može uzrokovati promjene u strukturi dentina (20). Zbog navedenih argumenata, za uklanjanje zaostatnog sloja u ovom je istraživanju odabrano ispiranje fiziološkom otopinom aktiviranom laserom Er:YAG i ispiranje i aktivacija laserom Er,Cr:YSGG (s demineraliziranom vodom iz vlastita sustava).

Rezultati su pokazali da je u skupini Er:YAG postignut najbolji učinak u uklanjanju zaostatnog sloja, ali u *push-out* testiranju ostvarene su najniže vrijednosti u usporedbi s kontrolnom skupinom i skupinom Er,Cr:YSGG. Iako razlike u srednjoj vrijednosti čvrstoće vezivanja nisu bile statistički značajne, ovo otkriće ipak je iznenadilo. U nekoliko studija ispitan je učinak ispiranja aktiviranog erbijskim laserima na vezivanje kolčića ojačanog vlaknima na dentin korijenskog kanala (21, 22) i autori su pronašli da je među testiranim skupinama u PIPS skupini ostvaren najbolji rezultat u testiranju čvrstoće vezivanja. Moguće objašnjenje za oprečne rezultate u spomenutim studijama i ovom istraživanju moglo bi se temeljiti na vrsti iriganasa aktiviranog erbijskim laserima i njegovoj interakciji s cementom upotrijebljenim za cementiranje kolčića ojačanog vlaknima. Za predtretman dentina upotrijebili su Ekim Akyuz i Erdemir 2015. godine (21) 2,5 posto NaOCl-a i 17 posto EDTA-e koji su bili aktivirani PIPS nastavkom, nakon čega je obavljeno završno ispiranje destiliranom vodom. Arslan i suradnici upotrijebili su 2015. (22) u svojem istraživanju samo destiliranu vodu aktiviranu PIPS nastavkom. U ovom je istraživanju za aktivaciju PIPS nastavkom lasera Er:YAG upotrijebljena fiziološka otopina. Tijekom rada PIPS nastavak aktivira molekule vode iz tekućina za ispiranje, što znači da je u ovom slučaju moguće da je tehnika PIPS uzrokovala oslobađanje disociranih natrijevih (Na^+) i kloridnih (Cl^-) iona koji su normalno okruženi hidratacijskom ovojnicom. Oslobođeni ioni možda su mogli uzrokovati promjene u kemijskoj strukturi dentina koje su utjecale na vezivanje cementa ili su, kao zaostale molekule, utjecale na stvrdnjavanje cementa. Iako je zaostatni sloj bio uklonjen, vezivanje u skupini PIPS bilo je slabije kvalitete negoli u kontrolnoj. U kontrolnoj skupini fiziološka otopina nije bila aktivirana i hidratacijska ovojnica ostala je oko disociranih Na^+ i Cl^- iona koji su time spriječeni da stvaraju ionske veze s drugim supstratima.

U skupini Er,Cr:YSGG za aktivaciju je upotrijebljena demineralizirana voda, zaostatni sloj bio je bolje uklonjen i ostvarene su više vrijednosti čvrstoće vezivanja u usporedbi s kontrolnom skupinom.

Ovo istraživanje bilo je ograničeno na *push-out* test izveden na individualnim kolčićima ojačanima vlaknima, samoadhezivnom cementu i dvjema tehnikama ispiranja aktiviranog erbijskim laserima. Dodatna istraživanja s različitim

the adhesive strength of the cement. In 2002, Calt and Serper reported that the use of EDTA for > 1 min can erode and damage root dentin (17). In two studies, an incompatibility of CHX (chlorhexidine) (18) and NaOCl (sodium hypochlorite) (19) with self-adhesive cement was found. In an attempt to avoid unwanted changes in root dentin, researchers have recently focused on removing the smear layer using laser irradiation, but found that lasers might cause changes in dentin structure (20). Due to the aforementioned arguments, for smear layer removal in the present study, irrigation with saline activated by Er:YAG and irrigation and activation with Er, Cr:YSGG laser and its own demineralized water system were chosen.

The results showed that while the Er:YAG group obtained the most efficient smear layer removal, in the end it scored the lowest bond strength values compared to LAI using Er,Cr:YSGG laser or the control group. Although the differences in mean bond strength values were not statistically significant, this finding was still surprising. Few studies have examined the effect of LAI using erbium lasers on FRC post bonding to root canal walls (21,22) and the authors found that among tested groups, PIPS groups obtained the best results in bond strength testing. A possible explanation for conflicting results between the abovementioned studies and the present research could be based on the type of irrigant activated by erbium lasers and its interaction with cement used for FRC post luting. In 2015, Akyuz Ekim and Erdemir (21) used 2.5 % NaOCl and 17 % EDTA for dentin pretreatment activated by PIPS tip with final irrigation with distilled water and in 2015, Arslan et al. used only distilled water activated by PIPS method (22). In the present research, saline, i.e. solution of NaCl (sodium chloride), was used for activation with Er:YAG laser PIPS tip. During the operation, the PIPS tip activates water molecules from the irrigation solutions, meaning that in this case the process of PIPS might have caused a release of dissociated sodium (Na^+) and chloride (Cl^-) ions which are normally surrounded by hydration shell. The released ions might have caused alterations in the chemical structure of dentin that affected the bonding of used luting cement or with possible cement residues interfering with the setting of the cement. Although the smear layer was removed, the bonding of PIPS group was inferior compared to the control group. In the control group, saline was not activated and hydration shell remained formed around dissociated Na^+ and Cl^- ions that were prevented from forming ionic bonds with other substrates. In the Er,Cr:YSGG group, demineralized water was used for activation, the smear layer was removed in a better way and higher bond strength values were obtained compared to the control group.

The present study was limited to push-out test performed on an individually formed FRC post, self-adhesive cement and two types of LAI. Further studies using different root canal irrigants, various types of FRC posts and types of luting cement and research methods such as evaluation of chemical changes in radicular dentin, nanoleakage evaluation along the bonded interface and adhesive interface micromorphology analysis, are needed to fully determine the effect of LAI on bonding of FRC posts to root canal dentin.

irigansima, vrstama kolčića ojačanih vlaknima, vrstama cementa i metodama istraživanja poput analize kemijskih promjena u korijenskom dentinu, testova nanopropuštanja i mikromorfološke analize površine dentina, potrebna su kako bi se u cijelosti odredio učinak ispiranja aktiviranog laserom na vezivanje kolčića ojačanih vlaknima na dentin korijenskoga kanala.

Zaključak

Uzimajući u obzir ograničenja provedenog istraživanja, može se zaključiti da ispiranje aktivirano PIPS ili RFT2 nastavcima erbijskih lasera ne utječe na čvrstoću vezivanja individualnih kolčića ojačanih vlaknima na dentin korijenskog kanala. Dodatna istraživanja potrebna su kako bi se u cijelosti utvrdio učinak ispiranja aktiviranog laserima na vezivanje vlaknima ojačanih kolčića na dentin korijenskog kanala.

Zahvala

Ovo istraživanje je provedeno uz pomoć potpore istraživanja Sveučilišta u Zagrebu 2015.

Sukob interesa

Nije bilo sukoba interesa.

Conclusion

Within the limitation of the present study, it could be concluded that LAI using erbium lasers with PIPS or RFT2 tip does not affect the bond strength of individually formed FRC posts to root canal dentin. Further studies are needed to fully determine the effect of LAI on bonding of FRC posts to root canal dentin.

Acknowledgements

This work was supported by a grant from the University of Zagreb, 2015.

Conflict of interest

None declared.

Abstract

Objective: The aim of this *in vitro* study was to investigate the effect of laser activated irrigation (LAI) using two erbium lasers on bond strength of individually formed fiber-reinforced composite (FRC) posts to root canal dentin. **Materials and methods:** Twenty-seven single-rooted human teeth were endodontically treated and after post space preparation divided into three groups (n=9 per group), according to the pre-treatment of post space preparation: 1) Conventional syringe irrigation (CSI) and saline; 2) Er.YAG photon-induced photoacoustic streaming (PIPS) technique and saline; 3) Er,Cr:YSGG activated irrigation with RFT2 tip. Two specimens from each group were used for SEM analysis. The remaining specimens (n=7 per group) received individually formed FRC post, everStick POST, luted with self-adhesive cement, G-CEM LinkAce. After cementation, the roots were perpendicularly sectioned into 1 mm thin sections and a push-out test was carried out (0.5 mm/min). The data were calculated as megapascals and were log transformed and statistically analysed using one-way ANOVA at the level of significance set at 5%. **Results:** In the control group, the smear layer was still present. In the Er:YAG group, the smear layer was removed. In the Er,Cr:YSGG group, the smear layer was partially removed. The Er,Cr:YSGG group achieved the highest bond strength values, followed by the control group and then the Er:YAG group, but no statistically significant difference was found in bond strength values in the tested group of post space pretreatment (p=0.564). **Conclusions:** LAI using two erbium lasers, with PIPS or RFT2 tip, did not affect the bond strength of individually formed FRC posts to root canal dentin.

Received: October 25, 2016
Accepted: December 1, 2016

Address for correspondence
Ivana Parčina Amižić, DMD
Health Center for County of Dalmatia
Department of Dental Medicine
Matoševa 2, 21 000 Split, Croatia
phone: +385 21 384 569
ivana.parcina@st.t-com.hr

Key words
Post and Core Technique; Solid-State Lasers; Root Canal Preparation; Fiberglass Reinforced Polymers

References

1. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent. 1999 May;27(4):275-8.
2. Bitter K, Noetzel J, Neumann K, Kielbassa AM. Effect of silanization on bond strengths of fiber posts to various resin cements. Quintessence Int. 2007 Feb;38(2):121-8.
3. Kececi AD, Ureyen Kaya B, Adanir N. Micro push-out bond strengths of four fiber-reinforced composite post systems and 2 luting materials. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008 Jan;105(1):121-8.
4. Mannocci F, Sherriff M, Watson TF, Vallittu PK. Penetration of bonding resins into fibre-reinforced composite posts: a confocal microscopic study. Int Endod J. 2005 Jan;38(1):46-51.
5. Mannocci F, Machmouridou E, Watson TF, Sauro S, Sherriff M, Pilecki P, et al. Microtensile bond strength of resin-post interfaces created with interpenetrating polymer network posts or cross-linked posts. Med Oral Patol Oral Cir Bucal. 2008 Nov 1;13(11):E745-52.
6. Makarewicz D, Le Bell-Rönnlöf AM, Lassila LV, Vallittu PK. Effect of cementation technique of individually formed fiber-reinforced composite post on bond strength and microleakage. Open Dent J. 2013 Jul 26;7:68-75.
7. Crispim da Silveira O, Bras da Silva R, Dametto FR, Machado CT, Souza dos Santos AJ, Cavalcanti AL. Effect of Endodontic Irrigating Solutions on the Micro Push-out Bond Strength of a Fibre Glass Dowel. Acta Stomatol Croat. 2014 Mar;48(1):16-24.
8. de Groot SD, Verhaagen B, Versluis M, Wu MK, Wesselink PR, van der Sluis LW. Laser-activated irrigation within root canals: cleaning efficacy and flow visualization. Int Endod J. 2009 Dec;42(12):1077-83.
9. Kolnick J. The clinical use of Er,Cr:YSGG laser in endodontic therapy. Roots. 2011;2:14-18.
10. DiVito E, Peters OA, Olivi G. Effectiveness of the erbium:YAG laser and new design radial and stripped tips in removing the smear layer after root canal instrumentation. Lasers Med Sci. 2012 Mar;27(2):273-80.

11. Al Shahrani M, DiVito E, Hughes CV, Nathanson D, Huang GT. Enhanced removal of Enterococcus faecalis biofilms in the root canal using sodium hypochlorite plus photon-induced photoacoustic streaming: an in vitro study. Photomed Laser Surg. 2014 May;32(5):260-6.
12. Olivi G, Crippa R, Iaria G, Kaitsas V, DiVito E, Benedicti S. Laser in endodontics (Part II). Roots. 2011;2:6-12.
13. Olivi G, DiVito E. Photoacoustic endodontics using PIPSTM: experimental background and clinical protocol. J Laser Heal Acad. 2012;(1):22–5.
14. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, Tay F, Ferrari M. The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. Eur J Oral Sci. 2004 Aug;112(4):353-61.
15. Le Bell AM, Lassila LV, Kangasniemi I, Vallittu PK. Bonding of fibre-reinforced composite post to root canal dentin. J Dent. 2005 Aug;33(7):533-9.
16. Bergoli CD, Amaral M, Boaro LC, Braga RR, Valandro LF. Fiber post cementation strategies: effect of mechanical cycling on push-out bond strength and cement polymerization stress. J Adhes Dent. 2012 Aug;14(5):471-8.
17. Calt S, Serper A. Time-dependent effects of EDTA on dentin structures. J Endod. 2002 Jan;28(1):17-9.
18. Stape THS, Menezes MDS, Barreto BDCF, Naves LZ, Aguiar FHB, Quagliatto PS, et al. Influence of chlorhexidine on dentin adhesive interface micromorphology and nanoleakage expression of resin cements. Microsc Res Tech. 2013 Aug;76(8):788-94.
19. Jardim P, Pereira-Cenci T, Badin C, Ferreira A, Jacinto R. The effect of endodontic chemicals on the retention of fiber posts luted using a self-adhesive cement. Appl Adhes Sci. 2014;2(1):20.
20. Bitter K, Noetzel J, Volk C, Neumann K, Kielbassa AM. Bond strength of fiber posts after the application of erbium:yttrium-aluminum-garnet laser treatment and gaseous ozone to the root canal. J Endod. 2008 Mar;34(3):306-9.
21. Akyuz Ekim SN, Erdemir A. Effect of different irrigant activation protocols on push-out bond strength. Lasers Med Sci. 2015 Nov;30(8):2143-9.
22. Arslan H, Akcay M, Saygili G, Keskı A, MeŞe İT, Gok A, Dalli M. Bond strength of self-adhesive resin cement to root dentin. Comparison of photon-initiated photoacoustic streaming technique with needle and ultrasonic irrigation. Acta Odontol Scand. 2015 Jul;73(5):348-52.