Push-out Bond Strength of Two Types of Dental Post Luted with Two Types of Cement at Two Different Root Levels

Istisna čvrstoća veze dviju vrsta intrakanalnih kolčića pričvršćenih dvjema vrstama cementa na dvjema različitim razinama korijena

Abstract

Objective: Endodontically treated teeth may require posts for retaining the core and replacing the coronal structures that have been lost. The objective of this study was to evaluate and compare the push-out bond strength between different types of post cemented with different types of luting cement at different types of root level. Material and Methods: In this in-vitro study, a total of 48 single-rooted permanent human teeth were decoronated, and the roots were treated endodontically. Following post space preparation, the sample was divided into four groups (n = 12 each) based on the types of post and cement. Two different types of post [GC everStick® POST (ES) and Parapost® Fiber Lux™ (PF)], and two different types of cement [G-CEM™ (G), and RelyXTM Unicem (R)] were used according to the manufacturer’s instructions. All roots were sectioned at the coronal and middle thirds with a thickness of 3±0.1mm. The Push-out bond strength (PBS) test was performed using a universal testing machine at a cross-head speed of 0.5mm/ min. The bond strength values were recorded, and the data were analyzed using the SPSS program. Apart from descriptive statistics, three-way ANOVA was used for the interaction of the independent variables (post, cement, and root level). For differences between the groups, the Mann-Whitney U test was used. A P-value of less than 0.05 was considered significant for all analyses. Results: Push-out bond strength of samples at the middle level (11.38±10.31 MPa), with PF posts (11.18±9.98 MPa), and of those luted with RelyXTM Unicem cement (13.26±8.73 MPa) was higher than that of their counterparts. The PBS means of RelyXTM Unicem cement at both root levels were much higher than PBS means of G-CEM cement. Three-way ANOVA test revealed a significant effect for each variable with a higher effect of cement (Sum of Squares=1310.690; P< 0.001). No significant difference (P= 0.153) was found between the coronal and middle parts and between ES and PF posts (P= 0.058). However, a highly significant difference (P<0.001) was found between RelyXTM Unicem and G-CEM cements. Conclusion: The type of cement had a significant effect on push-out bond strength with RelyXTM Unicem which had higher values than G-CEM. However, the type of post and root level had no significant effect on PBS, although Parapost® Fiber Lux™ and middle root level had higher values than their counterparts.

Key words

Dental Cements; Dentin-Bonding Agents; Bond Strength; Post and Core Technique

Introduction

Endodontically treated teeth have a reduced stiffness due to factors such as reduced moisture content of the tooth as well as the destruction of the coronal region of the tooth as a result of extensive dental caries [1], and this, in turn, increases the possibility of tooth fracture during function [2]. Thus, post systems have been introduced for retaining the core that replaces the lost coronal structures [3]. These systems have been used in clinical settings for many years [4]. The limitations of conventional metallic posts have been overcome by the development of fiber post whereby the posts flexibility has been increased, and a similar modulus of elasticity as dentin is achieved [5, 6]. Apart from elastic modulus, fiber posts also enhance several other superior properties such as high tensile strength, high fatigue, ability to be cemented with adhesive

Uvod

Endodontski liječeni zubi manje su kruti zbog čimbenika poput smanjenog sadržaja vlage u zubu te destrukcije kruna kao posljedice opsježnog zubnog karijesa (1), a to zauzvrat povećava mogućnost lomljenja zuba tijekom funkcije (2). Za to su uvedeni sustavi intrakanalnih kolčića za retenciju krunskog dijela nadogradnje koja nadomješta izgubljeno zubno tkivo (3). Ti su sustavi u kliničkoj primjeni već godinama (4). Ogrmištenja konvencionalnih metalićkih nadogradnji prevladala su se pojavom kompozitnih kolčića ojačanih vlakanima, pa se povećala njihova fleksibilnost i postigao modul elasticnosti sličan dentinu (5, 6). Osim modula elasticnosti, ojačani vlakanima imaju i druga povoljna svojstva, kao što su velika vlačna čvrstoća i mogućnost adhezijskog cementiranja da bi se izbjegla pojava trenja između kolčića i stijenki ko-
luting material to avoid friction development in between the posts and the walls of the root canal, thus leading to equal distribution of the force applied along the length of the post [7]. More than 90% success rates with zero root fracture incidence have been reported by clinical studies on restorations with fiber posts during the study duration [8]. On the other hand, it has been found that the most common failure was due to lack of retention of the fiber posts [9]. A fiber post is composed of a high percentage volume of continuous fibers that are embedded in a polymer matrix [10]. They are readily cured, and the matrix may be either a cross-linked epoxy resin matrix or a Bis-GMA matrix along with some fillers content [11]. The fiber content offers high tensile properties to the post, while the resin matrix plays a role in resisting compressive stresses [12, 13]. According to Baran et al., the incidence of post fracture in clinical settings is associated with the mechanical properties of the post itself [14]. In general, there are several factors that contribute to the mechanical strength of a fiber post and they include the individual properties of the fiber and matrix, polymerization shrinkage of the resin, intracanal irrigation systems, bonding between the fibers and matrix resin, the direction of the fibers as well as the volume fraction and proportion of fibers that were being impregnated into the resin matrix [11, 15, 16]. The retention of fiber posts is dependent on bond strength between the resin luting agent and the post and also the bond strength between the dentin and the resin luting agent [17]. When a successful bonding is achieved, it will minimize the wedging effect of the post in the root canal, thus reducing the risk of tooth fracture [18].

The effects of cement on the retention of the post have been widely investigated, and it was proved that the use of resin cements could significantly increase the retentive rate and frictional resistance of the tooth by providing adhesive bonding [2]. Various types of luting cement and adhesive systems are available for fiber post luting. They can be categorized into two main groups: self-etch and etch-and-rinse adhesive systems [19]. In this regard, several studies have been conducted to compare the effects of self-etch and etch-and-rinse adhesive systems on bond strength of fiber posts to root canal dentin. The push-out test has been used to evaluate the bonding of posts to root canal dentin. This test can provide a more accurate and better estimation of bonding strength compared to the conventional shear test because the fracture occurs parallel to the dentin-bonding interface, thus making it a true shear test. The Push-out test is also believed to be more reliable than a micro tensile test for bonded posts since the micro tensile test has been highly associated with large data distributions as well as a high number of premature failures that occur during specimen preparation. Apart from that, the Push-out test is also said to more closely simulate clinical conditions [20].

Since there are still considerably fewer data available in the literature regarding the differences on the bond strength of resin cement on everStick fiber post and indirect fiber composite post [21–23], this study was conducted to evaluate and compare the push-out bond strength between different types of posts cemented with different types of luting cement at two different levels of the root.
Material and methods

This in-vitro study was conducted in the Craniofacial Laboratory of School of Dental Sciences, Health Campus, University Sains Malaysia. Ethical approval for this study was obtained from the Ethics Committee (USM/JEPEM/18010029). A total of 48 single-rooted human permanent teeth were selected according to the inclusion criteria: a) Extracted human teeth with 15-16 mm straight single-rooted canal with mature apices, b) Extraction was due to periodontal or orthodontic reasons, and c) Minimal caries with sound coronal structure. The exclusion criteria were: a) Teeth with external caries (extend beyond the cementoenamel junction), and b) Teeth with extra canals, open apices, calcified canals, or curved roots. All soft tissues and debris around the teeth were removed using an ultrasonic scaler, and teeth were then stored in normal saline to prevent dehydration until the period of study. The materials used in this study are listed in Table 1. The teeth were randomly divided into four groups (n= 12 each) as follows: Group 1 (PF-G): Parapost® Fiber Lux™ luted with G-CEMTM, Group 2 (PF-R): Parapost® Fiber Lux™ luted with RelyXTM Unicem, Group 3 (ES-G): GC everStick®POST luted with G-CEMTM, and Group 4 (ES-R): GC everStick®POST luted with RelyXTM Unicem. Working length was standardized to 15±1mm [24, 25].

The access cavity was prepared using an endodontic access bur. The pulp tissue was removed using a barbed broach (Dentsply Maillefer, Switzerland). Apical patency was verified by passing ISO size 10 and 15 K-file (Dentsply Maillefer, Switzerland) through the root canal until the tip of the file was visible at the apical foramen. The irrigation of root canal filling was done by using normal saline and sodium hypochlorite solution. The length was then reduced by 1mm from the original working length. The canal was prepared with Universal Pro taper® (Dentsply Maillefer, Switzerland) using the crown down technique (S2 file size) and flaring of the canal was done using a F2 finishing file size. The final irrigation was done with normal saline solution after the irrigation to remove any remaining debris in the root canal after preparation. All canals were then dried with absorbent paper points. Obturation was done using a single Pro taper® Universal Gutta Percha size F2 with AH Plus sealer.

After that, a gutta-percha on the coronal and middle thirds of each root was removed using low-speed Gates Glidden drills number 2 and 3 (Dentsply Maillefer, Switzerland), leaving 5mm of intact gutta-percha to preserve the apical seal. A radiograph was taken for each tooth to ensure that there is no gutta-percha remains on the coronal and middle third sections of each root. Before the cementation procedure, the post space was irrigated with normal saline and dried with paper points. Both types of posts were then cemented with G-CEMTM (GC Corp., Tokyo, Japan) or RelyXTM Unicem (Coltene, Whaledent, USA) following the manufacturer’s instructions. The teeth were then sectioned perpendicular to the long axis of the tooth using a hard tissue cutter (Exact apparatus, Germany) at the coronal and middle levels of the root with 3±0.1mm thickness [26]. The push-out bond strength test of the samples was then performed with a uni-

Materijali i metode

Ovo istraživanje in vitro provedeno je u kraniofacionalnom laboratoriju Škole stomatoloških znanosti u Zdravstvenom kampusu Sveučilišta Sains u Maleziji. Odobrilo ga je Etičko povjerenstvo (USM/JEPeM/18010029). Odabrano je uku- pno 48 jednokorijenskih ljudskih trajnih zuba u skladu s kri- terijima za uključivanje: a) izvadeni zub s jednim ravnim ka- nalom dužine od 15 do 16 mm i zelim apskom; b) vađenje zbog parodoloških ili ortodontskih razloga; c) minimalni ka- rijes sa zdravim koronarnim tokvim.

Kriteriji za isključivanje bili su: a) zubi s opsežnim karije- som (koji se proteže preko caklinsko-cementnog spojijastog); b) zubi s dodatnim kanalima, otvorenim apskom, kalcičirani- nim kanalima ili zakrivljenim koriženima.

Sva meka tkiva i nečistoće oko zuba uklonjeni su ultra- zvučnim stručem, a zubi su zatim pohranjeni u fiziološku otopinu da bi se spriječila dehidracija do razdoblja ispitivanja. Materijali korišteni u ovom istraživanju navedeni su u tablici 1. Zubi su nasumično podijeljeni u četiri skupine (n = 12 sva- ka) kako slijedi: skupina 1 (PF-G): Parapost® Fiber Lux™ pričvršćen cementom G-CEMTM, skupina 2 (PF-R): Parapost® Fiber Lux™ pričvršćen cementom RelyX™ Unicem; skupi- na 3 (ES-G): GC everStick®POST pričvršćen cementom RelyX™ Unicem; skupina 4 (ES-R): GC everStick®POST pričvršćen cementom RelyX™ Unicem. Radna dužina standardizirana je na 15 ± 1 mm (24, 25).

Pristupni kavitet prepariran je endodontskom svrdlom. Pulpno tkivo uklonjeno je pulpokstiratorom (Dentsply Ma- illefer, Švicarska). Apikalno brltvljeno provjerenje je prola- skom instrumenata ISO veličine 10 i 15 (Dentsply Maillefer, Švicarska) kroz koriženjski kanal sve dok njegov vrh nije bio vidljiv na apikalnom otvoru. Koriženski kanal ispiran je fizi- ološkom otopinom i otopinom natrijeva hipoklorita. Dužina je zatim smanjena za 1 mm od prvotne radne duljine. Kanal je strojno obrađen uređajem Universal Pro taper® (Dentsply Maillefer, Švicarska) primjenom tehnike crown down (veliči- na instrumenata S2), a završeno je instrumentom F2. Za za- vršno ispiranje upotrijebljena je fiziološka otopina da bi se uklonila zaostala nečistoća iz koriženjskog kanala nakon in- strumentacije. Svi su kanali zatim osušeni papirnatim štapi- čima. Za optaraciju je korištena jedna gutaperka Pro taper® Universal veličine F2 i cement AH Plus.

Nakon toga je gutaperka iz koronarne i srednje trećine svakog korižena uklonjena svrdlama Gates Glidden broj 2 i 3 (Dentsply Maillefer, Švicarska) uz mali broj okretaja, ostav- ljajući 5 mm intakte gutaperke da bi se sačuvao apikalni pe- čat. Svaki je zub rendgenski snimljen kako bi se provjerilo da je u koronarnoj i srednjoj trećini svakog korižena nema ostataka gutaperke. Prije postupka cementiranja intrakanalni prostor ispran je fiziološkom otopinom i osušen papirnatim štapi- čima. Obje vrste količina zatim su zacentrirane cementima G-CEMTM (GC Corp., Tokyo, Japan) ili RelyX™ Unicem (Col- tened, Whaledent, SAD) slijedeći upute proizvođača. Zubi su zatim perezani okomitno na njihovu uzdužnu osnovu reza- čem tvrdog tkiva (Exact apparatus, Njemačka) na koroo- narnoj i srednjoj razini korižena na debljinu od 3 ± 0,1 mm (26). Ispitivanje vlačne čvrstoće uzoraka obavljeno je univer-
universal testing machine (Instron Corp., UK) at a cross-head speed of 0.5 mm/min. The force in Newton was applied, and the peak reading was recorded when a failure occurred. The readings were transferred to a master sheet, and the following formula was applied for the push-out bond strength:

$$\text{Push-out bond strength (PBS) = } \frac{\text{Force(N)}}{\pi r_1 r_2 \sqrt{(r_1 + r_2)^2 x h^2}}$$

where $r_1$: is the radius of the post from the upper part of the specimen, $r_2$: is the radius of the post from the lower part of the specimen, and $h$: is the height of the specimen.

The data were analyzed using the SPSS software program for Windows Version 25.0. Descriptive statistics in terms of means, standard deviations, minimum and maximum were presented. Factorial 3-way ANOVA test was used for the interaction of the three independent factors (post, cement, and root level). For differences between the groups, the Mann-Whitney U test was used. A P-value of less than 0.05 was considered significant for all tests.

Results

Table 1 shows the descriptive results of the PBS of the samples by type of post, type of cement, root level, and groups. In general, it can be noticed that the PBS means of at the middle level (11.38±10.31 MPa), Parapost® Fiber LuxTM post group (11.18±9.98 MPa), and RelyXTM cement group (13.26±8.73 MPa) were higher than that of their counterparts. For sub-groups, samples cemented with RelyXTM cement (regardless of the type of the post) were more retentive than those cemented with G-CEMTM cement (PF-R = 14.52±10.62 MPa and ES-R = 11.99±6.30 MPa compared to PF-G = 7.84±8.21 MPa and ES-G = 3.90±6.57 MPa). When the PBS was calculated for the groups at each root level (Table 2), the results revealed that the PBS means of the ES post and PF post were close to each other at the coronal level (6.62±7.33 MPa and 8.88±6.64 MPa, respectively). However, at the middle level, the PBS of PF post was much higher than that of ES post. The PBS means of RelyXTM cement at both root levels were much higher than PBS means of G-Cemen kidalicom (Instron Corp., UK) brzinom od 0.5 mm/min. Primijenjena je sila u njućima, a očitana je vršna sila u trenutku fraktura. Očitanja su prenesena na glavni list, a za izračun lomne sile primijenjena je sljedeća jednadžba:

$$\text{Vlačna čvrstoća (PBS) = } \frac{\text{Silu(N)}}{\pi (r_1-r_2)^2 (r_1+r_2) x h^2}$$

djele se: $r_1$: promjer kolčića na gornjem dijelu uzorka, $r_2$: je promjer kolčića na donjem dijelu uzorka, a $h$: visina uzorka.

Podaci su analizirani u softverskom programu SPSS za Windows, verzija 25.0. Prikazana je deskriptivna statistika u obliku srednjih vrijednosti, standardnih devijacija te minimalnih i maksimalnih vrijednosti. Faktorski trodimenzionalni ANOVA test upotrijben je za interakciju triju neovisnih čimbenika (kolčić, cement i razina korištena). Za razlike među skupinama korišten je Mann-Whitneyjev U-test. P-vrijednost manja od 0.05 smatrala se značajnom za sva ispitivanja.

Table 1: Means and SDs of push-out bond strength by root level, type of post, type of cement, and by subgroup

| Root level • Razina korijena | N  | Mean • Srednja vrijednost | SD  | Minimum | Maximum • Maksimum |
|-------------------------------|----|--------------------------|-----|---------|---------------------|
| Coronal • Koronarna          | 48 | 7.75                     | 7.01| 0.12    | 26.59               |
| Middle • Srednja             | 48 | 11.38                    | 10.31| 0.05    | 48.46               |
| Type of post • Vrsta kolčića |    |                          |     |         |                     |
| Fiber                        | 48 | 11.18                    | 9.98| 0.12    | 48.46               |
| EverStick                    | 48 | 7.94                     | 7.57| 0.05    | 29.19               |
| Type of cement • Vrsta cement|    |                          |     |         |                     |
| Rely-X                       | 48 | 13.26                    | 8.73| 0.28    | 48.46               |
| G-CEM                        | 48 | 5.87                     | 7.62| 0.05    | 26.59               |
| Subgroup • Podskupina         |    |                          |     |         |                     |
| PF-R                         | 24 | 14.52                    | 10.62| 0.28    | 48.46               |
| PF-G                         | 24 | 7.84                     | 8.21| 0.12    | 24.80               |
| ES-R                         | 24 | 11.99                    | 6.30| 0.91    | 29.19               |
| ES-G                         | 24 | 3.90                     | 6.57| 0.05    | 26.59               |

Rezultati

U tablici 1. su deskriptivni rezultati PBS-a uzoraka prema vrsti kolčića, vrsti cementa, razini korištena i skupini. Općenito se može uočiti da su srednje vrijednosti PBS-a na srednjoj razini (11.38 ± 10.31 MPa) u skupini Parapost® Fiber LuxTM (11.18 ± 9.98 MPa) i cementna skupina RelyXTM (13.26 ± 8.73 MPa) bile veće u usporedbi s ostalima. U podskupinama su uzorci pričvršćeni cementom RelyXTM (bez obzira na vrstu kolčića) imali bolju retenziju od onih pričvršćenih cementom G-CEMTM (PF-R = 14.52 ± 10.62 MPa i ES-R = 11.99 ± 6.30 MPa u usporedbi s PF-G = 7.84 ± 8.21 MPa i ES-G = 3.90 ± 6.57 MPa). Kad je izračunat PBS za skupine na svakoj razini korištena (tablica 2.), rezultati su pokazali da su srednje vrijednosti PBS-a za kolčiće ES i PF bile bližu jedne drugima na koronarnoj razini (6.62 ± 7.33 MPa i 8.88 ± 6.64 MPa). No na srednjoj razini bio je PBS za kolčićPF mnogo veći negoli za ES. Srednje vrijednosti PBS-a za cement RelyXTM na objema razinama korištena bile su mno- go veće negoli za G-CEM™. U podskupinama na koronar-
CERM™ cement. For sub-groups at the coronal level, posts luted with Rely-X cement (regardless of the type of post) had more PBS than those luted with G-CERM™ cement. However, at the middle level, PF posts luted with G-CERM™ cement had a retentive force almost similar to that of ES posts luted with RelyX™ Unicem cement, while PF posts luted with RelyX™ Unicem cement had much more retentive force than that of ES posts luted with G-CERM™ cement.

Three-way ANOVA test for the interaction effect of the independent variables (post, cement, and root level) revealed a significant effect for each variable (Table 3) with a higher noj razini imali su količići pričvršćeni cementom RelyX (bez obzira na vrstu količića) veće vrijednosti PBS-a od onih pričvršćenih cementom G-CERM™. No na srednjoj su razini postigli PF količići pričvršćeni cementom G-CERM™ retenciju silu sличну кoličицам ES прикрепленными цементом RelyX™ Unicem, а količići PF прикрепшени цементом RelyX™ Unicem имали су много већу retenciju silu од кoličица ES прикрепленных cementom G-CERM™.

Trosmjerna ANOVA za utjecaj interakcije neovisnih varijabli (količić, cement i razina korijena) pokazala je značajan učinak za svaku varijablu (tablica 3.) s većim učinkom ce-
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The interaction effect of the three variables was also significant (P = 0.044). Table 4 shows the difference between the groups among the independent variables. No significant difference (P = 0.153) was found between the coronal and middle parts based on the root level. Similarly, no significant difference (P = 0.058) was found between ES and PF posts based on the type of the post. However, a highly significant difference (P < 0.001) was found between RelyX™ Unicem and G-CEM™ cements based on the type of cement.

Table 4. Comparison between the groups by root level, type of post, and type of cement

| Type of Cement | Mean Difference * Srednja razlika | 95% CI of the Difference * 95% IP razlike | P |
|----------------|-----------------------------------|------------------------------------------|---|
| Coronal • Koronarna | -3.63 | -7.21 -0.05 | 0.153 |
| Middle • Srednja | 3.24 | -0.35 6.83 | 0.058 |
| Parapost | 7.39 | 4.07 10.71 | 0.000 |
| EverStick | 7.39 | 4.07 10.71 | 0.000 |
| Rely-X | 7.39 | 4.07 10.71 | 0.000 |
| G-CEM | 7.39 | 4.07 10.71 | 0.000 |

Discussion

The results obtained in the present study showed that Parapost® FiberLux™ and RelyX™ Unicem cement had recorded a higher push-out bond strength than GC everStick POST and G-CEM™ cement. Thus, the results of this in-vitro study require the rejection of the null hypothesis since there are significant differences in push-out bond strength that exist between different luting cements. A research conducted by Yahya et al. also showed that the highest bond strength was attained by RelyX™ Unicem as compared to Elite 100® zinc phosphate cement, Calibra and RelyX ARC resin cement [27]. Apart from that, a good bond strength was obtained for RelyX™ Unicem [28]. There are many possible explanations behind the superior bond strength of RelyX™ Unicem as compared to several other luting cements. The main possible reason may be the self-adhesive properties of RelyX™ Unicem due to the multifunctional phosphoric acid methacrylate material content, which is acidic and is able to cause demineralization of the tooth surface. This demineralization process is then followed by infiltration of the cements to the tooth structure and formation of chemical bonds with the hydroxyapatite structure of the tooth. Thus, there will be a formation of micromechanical retention and chemical adhesion to the hydroxyapatite structure. Besides, the well-known moisture-resistant property of RelyX™ Unicem is also one of the factors that lead to the superior bond strength values of this cement since moisture control is often compromised and hard to be controlled in root canals due to their anatomical structure [29]. The mechanical properties of cement are also affected by the degree of conversion and polymerization mode. It has been proven that a dual-cured cement such as RelyX™ Unicem exhibits more superior properties, the lowest contraction stress as well as higher degrees of cement (zbroj kvadrata = 1310.690; P < 0.001). Učinak interakcije triju varijabli također je bio značajan (P = 0.044). Tablica 4. prikazuje razliku između skupina za neovisne varijable. Nije ustanovljena značajna razlika (P = 0.153) između koronarnog i srednjeg dijela. Slično tomu, nije pronađena značajna razlika (P = 0.058) između količica ES i PF. No postojala je značajna razlika (P < 0.001) između cemenata RelyX™ Unicem i G-CEM™.

Rasprava

Rezultati dobiveni u ovom istraživanju pokazali su da su Parapost® FiberLux™ i RelyX™ Unicem cement postizali veću vlačnu čvrstoću od cemenata GC everStick POST i G-CEM™. Zato rezultati ovoga istraživanja in vitro zahtijevaju odbacivanje nulte hipoteze jer postoje značajne razlike u vlačnoj čvrstoći između različitih cemenata. Istraživanje koje su proveli Yahya i suradnici također je pokazalo da je najveća vlačna čvrstoća postignuta cemenatom RelyX™ Unicem u usporedbi s cinkfosfatnim cementima Elite 100®, Calibra i RelyX ARC [27]. Dobra vlačna čvrstoća zabilježena je i pri uporabi cemenata RelyX™ Unicem [28]. Mnogo je mogućih objašnjenja u vezi s najvećom vlačnom čvrstoćom cemenata RelyX™ Unicem u usporedbi s nekoliko drugih. Glavni razlog mogu biti samojektujuća svojstva RelyX™ Unicem zbog sadržaja metakrilata fosforne kiseline koji je kiseo i može izazvati demineralizaciju površine zuba. Nakon procesa demineralizacije slijedi infiltracija cementa u zubnu strukturu i stvaranje kemijskih veza s hidroksiapatitom. Tako se stvara mikromekanička retencija i kemijska adhezija na strukturi hidroksiapatita. Uz to, poznato svojstvo RelyX™ Unicem – otporna čvrstoća i visoka vlačna čvrstoća cementa jer je kontrola vlage često otežana i teško se kontrolira u korijenskim kanalima zbog njihove anatomske strukture [29]. Na mehanička svojstva cementa utječe i stupanj konverzije te način polimerizacije. Dokazano je da dualno stvrdnjajući cement kao što je RelyX™ Unicem ima superiorna svojstva, najmanje kontrakcijsko naprezanje te veći stupanj konverzije u usporedbi s cementima s drugim načinom polimerizacije (29 – 32).

Test vlačne čvrstoće u ovom istraživanju također je otkrio da količi FiberLux ima veću vrijednost vlačne čvrstoće od kol-
of conversion as compared to cements with another polymerization mode [29-32].

The Push-out bond strength test in this study has also revealed that Parapost FiberLux post has a greater bond strength value than GC everStick®POST when cemented with either G-CEM™ or RelyX™ Unicem. This indicates that stronger adhesion has occurred between Parapost FiberLux posts with both types of luting cement used, as compared to GC everStick®POST. In agreement with this result, a previous study by Alnaqbi et al. [33] has also found that the everStick®POST recorded a lower bond strength than RelyX Fiber post. Another previous study has also obtained a similar result where RelyX Fiber post has a higher bond strength when cemented with RelyX™ Unicem than that recorded of GC everStick®POST when cemented with similar types of luting cements [34]. There are several mechanisms that contribute to the adhesion between the fiber posts and resin cements, and these include micromechanical interlocking, chemical bonding and inter-diffusion [33]. The high elasticity properties of fiber-reinforced posts make the strain generated to be greatly reduced [35] and also provides the post with similar physical properties as natural dentin [10]. However, it is difficult for the posts with a cross-linked dimethacrylate-based or epoxy-based matrix to chemically bond to the luting resin cements due to the high cross-linking density properties since the monomers of the luting cement are unable to penetrate into the polymer matrix with a cross-linked nature [36, 37]. Thus, the inter-diffusion mechanism does not play a role in the process of adhesion of fiber posts to cross-linked epoxy-based fiber-reinforced posts.

For GC everStick®POST, it consists of a semi-interpenetrating polymer network (IPN), whereby there are two independent polymer networks that are not linked by chemical bonds [38]. The manufacturer has claimed that the bond of everStick®POST with the pre-polymerized semi-IPN and the resin cements are improved by the mechanism of inter-diffusion bonding. When the resin cements are in contact with the surface of the IPN resin matrix, the monomers of the cement diffuse into the linear phases of the IPN polymer matrix, and the polymerization then becomes inter-locked. everStick®POST has the content of poly Bis-GMA as the matrix, and the polymerization then becomes inter-locked. everStick®POST with the pre-polymerized semi-IPN and the resin cements are improved by the mechanism of inter-diffusion bonding. When the resin cements are in contact with the surface of the IPN resin matrix, the monomers of the cement diffuse into the linear phases of the IPN polymer matrix, and the polymerization then becomes inter-locked. everStick®POST has the content of poly Bis-GMA as the matrix, and the polymerization then becomes inter-locked. everStick®POST has the content of poly Bis-GMA as the matrix, and the polymerization then becomes inter-locked. everStick®POST has the content of poly Bis-GMA as the matrix, and the polymerization then becomes inter-locked.

According to Zhang and Matinlinna, the difference in the types of glass fiber content of these two types of posts is one of the factors that affect their mechanical properties. Parapost Fiber Lux™ post contains S-glass fibers that are known to have the greatest tensile strength among all types of glass fibers. As for GC everStick®POST, this post has the E-glass fibre content, which is enriched with a layer of PMMA [37]. This partially linear phase of everStick®POST with the pre-polymerized semi-IPN and adhezijskim cementom poboljša mehanizmom interdifuzijskog vezanja. Kad su kompozitni cementi u kontaktu s površinom IPN-a smolaste matrice, monomeri cementa difundiraju u linearnu fazu IPN-a i polimerizacijom se uzajamno zaključuju. everStick®POST sadržava poli-bis-GMA kao umreženu fazu i polimerni matični materijal. Proizvođač tvrdi da je veza everStick®POST-a s prepolimeriziranim polou-IPN-om jedna od razloga za izrada cementa, u usporedbi s kolčićima GC everStick®POST. U skladu s tim rezultatom, istraživanje Alnaqbi i suradnika [33] također je pokazalo da je everStick®POST postigao slabiju veznu čvrstoću u odnosu prema RelyX Fiberu. U jednom drugom istraživanju također je dobiven sličan rezultat – RelyX Fiber imao je veću veznu čvrstoću kada je bio pričvršćen cementom RelyX™ Unicem negli GC everStick®POST kad je cementiran sličnim vrstama cemenata [34]. Nekoliko mehanizama pridonosi adheziji između vlakana i cementa, a oni uključuju mikromehaničko spajanje, kemijsko vezivanje i inter-difuziju [33]. Visoka elastičnost kompozitnih količića ojačanih vlaknima čine da se generirano naprezanje znatno smanji [35], a također imaju slična fizička svojstva kao prirodni dentin [10]. Teško će se količići s umreženom matricom na bazi dimetakrilata ili epoksidne smole kemijski vezati na kompozitne cemente zbog velike gustoće jer monomeri iz cementa ne mogu prodijeliti u umreženu polimernu matricu [36, 37].

GC everStick®POST sastoji se od poliinterpenetrirajuće polimerne mreže (IPN), pri čemu postoje dvije zasebne polimerne mreže koje nisu povezane kemijskim vezama (38). Proizvođač tvrdi da je veza everStick®POST-a s prepolimeriziranim polou-IPN-om mehanizmon interdifuzijskog vezanja. Kad su kompozitni cementi u kontaktu s površinom IPN-a smolaste matrice, monomeri cementa difundiraju u linearnu fazu IPN-a i polimerizacijom se uzajamno zaključuju. everStick®POST sadržava poli-bis-GMA kao umreženu fazu i polimerni matični materijal (PMMA) kao linearnu fazu, a površina everStick®POST-a obogaćena je slojem PMMA-e (37). Ta djelomična linearna faza omogućuje postupak inter-difuzijskog povezivanja jer će se ta difuzija dogoditi samo ako je polimerni supstrat potpuno ili djelomično linearan (38). Vrste cementa korištene u našem istraživanju imale su parametre topljivosti slične PMMA-i, što omogućuje prednost u obliku dubljeg prodiranja u polu-IPN polimernu strukturu everStick®POST-a i pridonosi velikoj čvrstoći (33).

Prema stajalištu Zhanga i Matinlinnija razlika u sadržaju staklenih vlakana u tim dvjema vrstama količića jedan je od čimbenika koji utječu na njihova mehanička svojstva. Parapost Fiber Lux™ sadržava tip S staklenih vlakana za koja se zna da postižu najveću vlačnu čvrstoću među svim vrstama staklenih vlakana. Kad je riječ o količićima GC everStick®POST, oni sadržavaju tip E-staklenih vlakana za koje se zna da postižu manju vlačnu čvrstoću u odnosu prema S-vlaknama [39]. Drugi mogući razlog jest razlika u obliku samog količića. Parapost Fiber Lux™ se sužava, pri čemu ima cilindričnu konfiguraciju koronarno i koničnu konfiguraciju apikalno. To oponaša prirodnu anatomsku strukturu korijenskog kanala te dodatno poboljšava prilagodbu količića u korijenskom kanalu. No GC everStick®POST paralelnog je oblika i manje oponaša anatomiju korijenskog kanala, a kaktdak, kao u slučaju proširenog kanala, može biti potrebno više od jednog količića po kanalu. Zato se može pretpostaviti da je to možda jedan od razloga za dobru veznu čvrstoću
fibers type, which is known to have a lower tensile strength compared to S-glass fibers [39]. Another possible reason is the difference in the shape of the post itself. Parapost Fiber Lux™ post is tapered in shape whereby it has a cylindrical configuration coronally and conical configuration apically. This closely mimics the natural anatomical structure of the root canal, thus further enhancing the adaptation of the post in the root canal. However, GC everStick®POST is parallel in shape which less mimics the anatomy of the root canal, and in certain cases such as in widened canal, more than a single post may be required to be packed into the canal. In this way, it may be hypothesized that this may be one of the reasons behind the superior bond strength of Parapost Fiber Lux™ compared to GC everStick®POST [34].

Although the middle third of the root had higher push-out bond strength than coronal third irrespective the type of post or cement, this difference was in favor of the coronal part when the type of cement was considered. Therefore, the push-out bond strength of the coronal third cemented with RelyX™ Unicem cement was higher than the middle third cemented with GC-CEM™ cement. This result is comparable to that obtained by Pereira et al. [40] where a significant difference was noticed with different types of cement. This might be attributed to the number of dentinal tubules in the coronal third of the root, which is higher and decreasing gradually towards the apical third [41]. This, in turn, might enhance the adhesion of the cement to the dentin by penetration of the resin to dentin tubules [3]. Some limitations of the current study should be acknowledged. The results are restricted to specific products, hence we cannot make generalizations about all other products. The environment of in-vitro studies is somewhat different from the clinical situation, therefore, further clinical follow-up studies are recommended to simulate the real circumstances.

Conclusion

Within the limitations of this in-vitro study, it can be concluded that the type of cement had a significant effect on push-out bond strength with RelyX™ Unicem cement being significantly more adhesive than GC-CEM™ cement. However, the type of post and root level had no significant effect on PBS, although Parapost® Fiber Lux™ and the middle root level had higher values than their counterparts.

Conflicts of Interests

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

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Zaključak

Uzimajući u obzir ograničenja ovoga istraživanja in vitro može se zaključiti da je vrsta cementa značajno utjecala na vjeznu čvrstoću, pri čemu se cementom RelyX™ Unicem postižala bolja adhezija negoli cementom GC-CEM™. No vrsta kolčića i razina korijena nisu značajano utjecali na PBS, iako su Parapost® Fiber Lux™ i srednja razina korijena imali veće vrijednosti od ostalih skupina.

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Dvije vrste cementa na dvjema razinama korijena Alhajj i sur.

Sažetak

Cilj: Endodontski liječeni zubi mogu zahtijevati izradu nadogradnje za osiguravanje retencije i nadomješanje izgubljenog zubnog tkiva. Cilj ovog istraživanja bio je procijeniti i usporediti vlačnu čvrstoću različitih vrsta intrakanalnih kolčića pričvršćenih različitim vrstama cementa na različitim razinama korijena.

Materijal i metode: U ovom istraživanju *in vitro* dekoronirano je ukupno 48 jednokorijenjskih trajnih ljudskih zuba, a korijeni su endodontski izliječeni. Nakon preparacije prostora za nadogradnju uzorci su podijeljeni u četiri skupine (n = 12 svaka) na temelju vrste kolčića i cementa. Dvije različite vrste kolčića (GC EverStick® POST ES i Parapost® Fiber Lux™ (PF)) te dvije različite vrste cementa (G-CEMTM (G) i RelyX™ Unicem (R)) korišteni su prema uputama proizvođača. Svi korijeni prerezani su u koronarnoj i srednjoj trećini na debljinu od 3 ± 0,1 mm. Ispitivanje vlačne čvrstoće provedeno je na univerzalnoj kidalici s brzinom okretanja glave od 0,5 mm/min. Zabilježene su vrijednosti vazačne čvrstoće, a podatci su analizirani u programu SPSS. Osim deskriptivne statistike, upotrijebljena je trosmjerna ANOVA za analizu interakcija neovisnih varijabli (vrsta kolčića, cement i razina korijena). Za razlike među skupinama primijenjen je Mann-Whitneyev U-test. P-vrijednost manja od 0,05 smatra se statistički značajnom.

Rezultati: Vlačna čvrstoća uzoraka na srednjoj razini korijena (11,38 ± 10,31 MPa) s PF-količićima (11,18 ± 9,98 MPa) je veća od čvrstoće uzoraka na obje razini korijena (11,38 ± 10,31 MPa) i 10,93 ± 9,64 MPa) s Unicem količićima u usporedbi s drugim skupinama. Srednje vrijednosti za PBS RelyX™ Unicem na obje raznine korijena bile su veće od 11,38 ± 10,31 MPa za G-CEMTM. Trosmjerna ANOVA pokazala je značajnu razliku za G-CEMTM. Ne postojala je značajna razlika između koronarnog i srednjeg dijela te između stupaca ES i PF (P = 0,058). No, zabilježena je značajna razlika između RelyX™ Unicem i G-CEMTM. Iako se javlja značajna razlika između univerzalnih kidalica, korijen Post ACT® sa 12150 Kubang Kerian, Kelantan, Malaysia zahtijeva značajno više vrijednosti u usporedbi s ostalim skupinama.

Ključne riječi: stomatološki cementi; dentinski adheziv; vlačna čvrstoća; tehnika kolčića; endodontski liječenje zuba

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