ACTA
STOMATOLOGICA
CROATICA
www.ascro.hr

Acta Stomatol Croat. 2008;42(1):30-40.

IZVORNI ZNANSTVENI RAD
ORIGINAL SCIENTIFIC PAPER

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Otpornost na frakturu gornjih pretkutnjaka s kanalom punjenim dentinskim adhezivnim sustavima

Fracture Resistance of Root-Filled Maxillary Premolar Teeth Restored with Current Dentin Bonding Adhesives

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Sažetak
Svrha istraživanja bila je usporediti otpornost na frakturu gornjih pretkutnjaka s punjenim kanalima, a restaurirani različitim dentinskim adhezivnima (DA). **Materijal i metode:** Osamdeset ekstrahiranih jednokorijenskih ljudskih maksilarnih pretkutnjaka nasumce su podijeljeni u osam skupina (n=10). Prva skupina (kontrolna) nije bila preparirana. Kod skupina od 2 do 8 korijeni zuba bili su punjeni i preparirani MOD kavitetima. Skupina 2. ostala je bez restauracije. Skupine od 3 do 8 restaurirane su sljedećim dentalnim adhezivom: iBond (Heraeus Kulzer), G-Bond (GC Co.), Xeno III (Dentsply/Caulk), AdheSe (Ivoclar Vivadent), Clearfil Protect Bond (Kuraray) i Clearfil Tri-S Bond (Kuraray). Sve su preparacije u daljnjem postupku bile potpuno restaurirane kompozitima (Renew, Bisco). Svi su uzorci zatim bili pohranjeni 24 sata na 100-postotnoj vlažnosti i na temperaturi od 37 ºC. Nakon toga obrađeni su cikličkom toplinom 500 puta između 5° i 55 °C. Tlačno opterećenje zuba ispitano je univerzalnim strojem pri brzini od 1 mm min-1 sve dok se nije pojavila fraktura. Podaci su uneseni u Newton (N) i ispitani jednostranom ANOVA-om i Tukeyevim post-hoc testom. **Rezultati:** Srednja vrijednost opterećenja potrebnog za frakturu uzorka za svaku je skupinu bila sljedeća: skupina 1: 984,00 ± 116.27a; ; skupina 2: 167,30 ± 47,26b ; skupina 3: 872,30 ± 164,99a ; skupina 4: 848,70 ± 157,84a ; skupina 5: 916,30 ± 246,19a ; skupina 6: 863,20 ± 197,69a ; skupina 7: 802,20 ± 183,84a i skupina 8: 870,70 ± 126,48 a. Slična slova pokazuju statistički slične vrijednosti (P>0,05). **Zaključak:** Vrsta entinskog adheziva ne utječe na otpornost zuba na frakturu.

Zaprimljen: 29. rujna 2007.
Prihvaćen: 12. veljače 2008.

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Ključne riječi
pretkutnjak; premolar; lom zuba; materijali za punjenje korijenskih kanala; sredstva za svezivanje dentina; kompozitne smole

Uvod

Okluzalne sile i lateralne ekskurzije deformiraju kvržicu zuba, iako su intaktni zubi čvrsti, a stres tijekom trenja između okludiranih površina uglavnom apsorbiran u periodontalni ligament (1, 2). Karijesna lezija, trauma i pretjerano uklanjanje ostalog dentina tijekom liječenja korijenskog kanala, znatno smanjuju čvrstoću zuba i zbog okluzalnih sila povećavaju mogućnost fraktura kvržica (3). Veza između opsežnih restorativnih postupaka i visokih okluzalnih opterećenja, u kombinaciji s kontaktima u lateralnoj ekskurziji, češće omogućuje frakture (4). Zbog toga se zubi s punjenim kanalima smatraju posebno ugroženima. Zato se liječenje korijenskog kanala ne smije smatrati završenim sve dok se ne postavi završna koronarna restauracija. Ona kod zuba s punjenim korijenom zadovoljava estetiku i funkciju, čuva ostale zubne strukture i sprječava mikropropuštanja (5). Prijašnja istraživanja pokazala su da se za završnu restauraciju mogu koristiti potpuno lijevani nadomjestak (6) kao indirektna restauracija koja prekriva kvržice (7) te kompleksna restauracija amalgamom (8) ili kompozitnim materijalom (9).

U različitim istraživanjima istaknut je znatan porast otpornosti na frakturu kod zuba s punjenim kanalima ako su intrakoronarno restaurirani kompozitnom smolom s uobičajenom procedurom jetkanja i adhezije (9-11).

Posljednjih godina mnogo je novih dentalnih adheziva (DA) sa suvremenim mehaničkim i fizičkim svojstvima. Kako bi se smanjila osjetljivost na tehniku i čimbenike vezane za materijale koji utječu na čvrstoću veza, razvio se pristup samojetkajućih adheziva. Oni se nanose jedanput (kondicioner-primer-bond) ili se rabi samojetkajući adheziv koji se aplicira dva puta (12). To je smanjilo broj aplikacija i povećalo čvrstoću veze između kompozita i dentina te omogućilo restauraciju bez propuštanja. Pretpostavlja se da su ti adhezivi poboljšali adheziju i čvrstoću veza između smole i strukture zuba tako omogućujući prodiranje, impregnaciju i zaplet vezivnog sredstva u dentinske supstrate gdje se polimeriziraju *in situ* i stvaraju smolom-pojačane dentinske slojeve (6). Svrha istraživanja bila je usporediti otpornost kvržica na frakturu kod maksilarnih pretkutnjaka s punjenim korijenom restauriranim samojetkajućim adhezivom koji se aplicira jedanput i samojetkajućim adhezivom koji se nanosi dva puta.

Introduction

Cusps deform due to occlusal forces and lateral excursions, even though intact teeth are stiff (1), and the stresses generated during friction between occluding surfaces are mainly absorbed in the periodontal ligament (2). Caries, trauma and the excessive removal of rest dentin during root canal treatment produce a substantial reduction in tooth strength and increase cuspal fracture under occlusal load (3). The association between extensive restorative procedures and high occlusal loads, combined with lateral excursive contacts, leads to a higher susceptibility to fracture (4). Accordingly, root-filled teeth are considered especially at risk. Thus, root canal treatment should not be considered complete until the final coronal restoration has been placed. An optimal final restoration for root-filled teeth maintains aesthetics and function, preserves remaining tooth structure, and prevents microleakage (5). Previous studies indicated that complete cast coverage (6), an indirect cast restoration covering the cusps (7), complex amalgam restorations (8) or composite materials (9) can be used for final restorations.

Various studies have reported a significant increase in the fracture resistance of root filled teeth when restored with a resin composite material intracoronally with routine acid-etch and bonding procedures (9-11).

In recent years, numerous new dentine bonding adhesives (DBAs) with new mechanical and physical properties have appeared. To reduce technique-sensitive and materials related factors that affect bond strength a self etch approach involving either one (conditioner-primer-bonding agent) or two-step self etch adhesives (conditioner-primer, bonding agent) applications have been developed (12). These DBAs have decreased the number of application time and increased consistency of bond strength of composite resins to dentin, as well as produced leak-free restorations. It is assumed that these bonding adhesives improve the adhesive capability and bonding strength of resins to tooth structure by promoting penetration, impregnation and entanglement of the coupling agents into dentinal substrates where they polymerize *in situ* and create zones of resin-reinforced dentin layers (6). The aim of this *in vitro* study was conducted to compare the cusp fracture resistance of root-filled maxillary premolar teeth restored with one-step self etch and two-step self etch adhesives.

Materijali i načini rada

Izbor uzorka

Materijali korišteni u ovom istraživanju te njihov sadržaj nalaze se su u Tablici 1. Za ispitivanje se koristilo osamdeset tek ekstrahiranih maksilarnih pretkutnjaka sličnih dimenzija (meziodistalna i bukolingvalna veličina krune te cervikoapikalna dužina

Materials and Methods

Specimen selection

The materials used in this study and their composition are showed in Table 1. Eighty freshly extracted human mature maxillary premolar teeth with similar dimensions (the mesiodistal and buccolingual size of the crown and the cervico-apical length

Tablica 1. Korišteni materijali i njihovi sastavi
Table 1 The materials used and their composition.

Materijal • Material	Serijski broj • Batch Number	Proizvođač • Manufacturer	Sastav • Composition
iBond (samojetkajući u jednom koraku • one-step self-etch)	010075	Heraeus Kulzer, Hanau, Njemačka • Germany	4-META, UDMA, glutaraldehid, aceton, voda, kamforkinon • 4-META, UDMA, gluturaldehyde, acetone, water, camphorquinone
G-bond (samojetkajući u jednom koraku • one-step self-etch)	0503281	GC Co, Tokijo, Japan	4-MET, monomeri fosfatni estera, UDMA, voda, aceton, punilo silicijeva dioksida, fotoinicijator. • 4-MET, phosphate ester monomer, UDMA, water, acetone, silica filler, photo initiator.
Xeno III Bond (samojetkajući – jenadput se aplicira • one-step self-etch)	04411001721	Dentsply/Caulk, Milford, DE, SAD • USA	Liquid A: HEMA, water, ethanol, BHT, Nanofiller Liquid B: Pyro-EMA-SK, PEM-F, UDMA, BHT, EPD • Liquid A: HEMA, water, ethanol, BHT, Nanofiller Liquid B: Pyro-EMA-SK, PEM-F, UDMA, BHT, EPD
Adhese Bond (samojetkajući – nanosi se dva puta • two-step self- etch)	G13221	Ivoclar Vivadent, Schaan, Liechenstein	Primer: phosphoric acid acrylate, Bis-acrylic acid amine, voda, inicijatori, stabilizatori • Primer: phosphoric acid acrylate, Bis-acrylic acid amine, water, initiators, stabilizers Adhezivni komponent: HEMA, visoko dispergirani silikon dioksid, inicijatori, stabilizatori • Bonding component: HEMA, highly dispersed silicone dioxide, initiators, stabilizers
Clearfil Protect Bond (samojetkajući – nanosi se dva puta • two-step self- etch)	41114	Kuraray, Osaka, Japan	Primer: HEMA, MDP, MDPB, voda. Bond: MDP, Bis-GMA, HEMA, hidrofobni dimetilakrilat, di- kamforkinon, N,N-dietanol-p-toluidin, koloidi silaniziranog silicijeva dioksida, površinski obrađen natrij florid • Primer: HEMA, MDP, MDPB, water. Bond: MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate, di-camphoroquinone, N,N-diethanol-p-toluidine, silanated colloidal silica, surface treated sodium fluoride.
Clearfil Tri-S Bond (samojetkajući – nanosi se jedanput • One-step self-etch)	41116	Kuraray, Osaka, Japan	MDP, Bis-GMA, HEMA, kamforkinon, etilni alkohol, voda, koloidi silaniziranog silicijeva dioksida. • MDP, Bis-GMA, HEMA, camphorquinone, ethyl alcohol, water, silanated colloidal silica.
Renew (hibridna kompozitna smola • hybrid composite resin)	0400003469	bisco, Schaumburg, SAD • USA	Monomer Bis-EMA, dimetakrilat Punilo (%59wt, %73vol): barijevo staklo, silicijev dioksid, titanov dioksid. • Monomer Bis-EMA, dimethacrylate Filler(%59wt, %73vol):bariumglass, silica,titanium dioxide

4-META: 4-metacryloyloxy ethyl trimellitic anhydride, **4-MET:** 4-methacryloylox ethyl trimellitic acid, **HEMA:** Hidroksietil metakrilat, **PEM-F:** pentamethacryloxyethyl-cyclophosphazen mono fluoride, **BHT**:2, 6-di-tert-butil-p hidroksi toluen, **EPD:** p-dimetilamino etil benzoat, **Pyro-EMA:** tetrametacrioksietil-pirofosfat, **UDMA:** uretan dimetakrilat, **MDP:** 10-methacryoloyloxydecyl dihydrogen phosphate, **5-NMSA:** *N*-metacriloksil-5-aminosalicilna kiselina, **MDPB:** 12-methacryloyloxyd odecylpyridinium bromide, **Bis-GMA:** bisfenol-A-etil metakrilat, **bis-EMA**, bisfenol-A-etil metakrilat •
4-META: 4-methacryloyloxy ethyl trimellitic anhydride, 4-MET: 4-methacryloylox ethyl trimellitic acid, HEMA: hydroxyethyl methacrylate, PEM-F: pentamethacryloxyethyl-cyclophosphazen mono fluoride, BHT:2, 6-di-tert-butyl-p hydroxy toluene, EPD: p-dimethylamino ethyl benzoate, Pyro-EMA: tetramethacryoxyethyl-pyrophosphate, UDMA: urethane dimethacrylate, MDP: 10-methacryoloyloxydecyl dihydrogen phosphate, 5-NMSA: N-methacryloxyl-5-aminosalicylic acid, MDPB: 12-methacryloyloxydod ecylpyridinium bromide, Bis-GMA: bis-phenol a diglycidylmethacrylate, bis-EMA, ethoxylated BisGMA

korijena) bez karijesne lezije, abraziranih površina, oštećenja od kliješta ili frakture. Zubi su bili očišćeni od ostataka mekog tkiva te pohranjeni do uporabe u fiziološkoj otopini na temperaturi od 4°C .

Procedure restauracije

Zubi su bili nasumce podijeljeni u osam skupina i svaka se sastojala od deset zuba pripremljenih na sljedeći način:

Skupina 1. - nisu obavljene nikakve preparacije kaviteta i koristila se kao kontrolna skupina.

U skupinama od 2. do 8. trepanacijski su otvori bili napravljeni dijamantnim svrdlom na turbini s vodenim hlađenjem te je nakon toga ekstripacijskom iglom uklonjeno pulpno tkivo. Igla veličine *15* bila je unesena u svaki kanal dok se nije vidjela na vršku korijenskog kanala. Radna dužina odredila se tako da se oduzeo jedan milimetar od izmjerene dužine. Kanali su bili prošireni do igle broj *50* na radnoj dužini koristeći se step-back tehnikom. Koronarni dio svakog kanala bio je proširen svrdlom Gates Glidden veličine 1 do 3 pomoću kolječnika.

Kanali su zatim isprani s 3mL 2,5-postotnog NaOCl-a s iglom promjera 27G i to nakon svake instrumentacije. Nakon biomehaničke preparacije kanali su se 30 sekundi ispirali s 3 mL 15-postotnog EDTA kako bi se uklonio zaostali sloj. Završno ispiranje kanala obavljeno je s 3 mL 2,5-postotnog NaOCl-a. Kanali su bili posušeni apsorbirajućim papirnatim štapićima (paper point) te napunjeni gutaperkom (Sure-Endo, Seul, Južna Koreja) i AH 26 (Dentsply De-Trey, Konstanz, Njemačka) kao sredstvom za brtvljenje tehnikom hladne lateralne kondenzacije. MOD kaviteti preparirani su sve do ulaza u kanale, tako da je debljina bukalnog zida zuba bila 2 mm na bukalno-okluzalnoj površini, 2,5 mm na caklinsko-cementnom spojištu (CCS), 1,5 mm na lingvalnoj okluzalnoj površini i 1,5 mm na lingvalnom CCS (Sl. 1). Kaviteti su preparirani prema jednoličnom obliku, kako bi nadoknadili minimalne razlike bukalne i palatinalne stijenke zuba. Dimenzije kaviteta bile su izmjerene pomoćnom mjerkom s osjetljivošću na 0.1 mm.

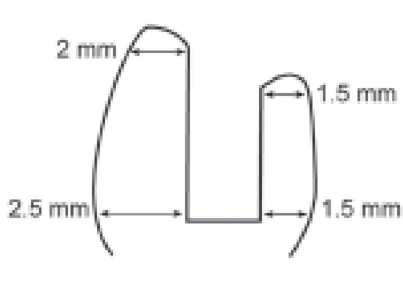
of the roots) and without caries, abrasion cavities and injury from forceps or fractures were used. The teeth were cleaned of debris and soft tissue remnants and were stored in physiological saline at +4 °C until required.

Restorative procedures

The teeth were then randomly assigned into eight groups of ten teeth each and were prepared as follows:

Group 1 - This group did not receive cavity preparation or root canal treatment and was used as the control.

From groups 2-8: endodontic access cavities were prepared using a water-cooled diamond bur in a high speed handpiece and the pulp tissue was removed with barbed broaches. A size 15 K-file was introduced into each canal until it could be seen at the apical foramen. The working length was determined by subtracting 1 mm from this length. The canals were prepared to a size 50 K-file at working length with a stepback technique. The coronal portion of each canal was enlarged with Gates Glidden burs sizes 1 through 3 in a slow-speed contra-angle handpiece. The canals were irrigated with 3 mL of 2.5% NaOCl solution using a 27 gauge endodontic needle after the use of each instrument. Following biomechanical preparation, the canals were irrigated with 3 mL of 15% EDTA solution for 30 s to remove smear layer. Final canal irrigation was accomplished with 3 mL of 2.5% NaOCl solution. Canals were dried with absorbent paper points and filled with gutta-percha (Sure-Endo, Seoul, Korea) and AH 26 sealer (Dentsply De-Trey, Konstanz, Germany) using cold lateral condensation. MOD cavities were prepared in the teeth down to the canal orifices so that the thickness of the buccal wall of the teeth measured 2 mm at the buccal occlusal surface, 2.5 mm at the cemento-enamel junction (CEJ), 1.5 mm at the lingual occlusal surface and 1.5 mm at the lingual CEJ (Fig. 1). The cavities were prepared in uniform shape to compensate for the minimal differences, buccal and palatinal walls of the teeth. The dimensions of the cavities were measured with a caliper at 0.1 mm sensitivity.



Slika 1. Shematski prikaz MOD kaviteta u premolarnom zubu

Figure 1 The schematic representation of MOD cavity in premolar teeth.

Skupina 2. - ostala je bez restaurativnog nadomjestka nakon preparacije MOD kaviteta.

Skupina 3. (iBond skupina) - kaviteti su bili očišćeni i posušeni. Zatim je prema uputama proizvođača apliciran samojetkajući adhezivni sustav iBond (Heraeus Kulzer, Hanau, Njemačka). Bila su nanesena tri dodatna sloja iBonda, a zatim se čekalo 30 sekundi. Površine su se lagano sušile dok više nije bilo pomaka adheziva (vidljivo sjajna površina), a zatim su 20 sekundi polimerizirane svjetlom.

Skupina 4. (G-Bond Skupina) – na površinu kaviteta nanesen je prema uputama proizvođača G-Bond (GC Co., Tokio, Japan). Adheziv se lagano sušio pusterom i zatim je 10 sekundi polimeriziran svjetlom.

Skupina 5. (Xeno III Bond Skupina) - jednaka količina tekućine A **i** tekućine B Xeno III Bonda 5 sekundi su se dobro miješale. Zatim je adhezivna smjesa aplicirana na caklinske i dentinske površine te ostavljena 20 sekundi. Kako bi se uklonilo otapalo, adheziv se sušio najmanje 2 sekunde laganom strujom zraka. Zatim je polimeriziran svjetlom 10 sekundi.

Skupina 6. (AdheSe Bond Skupina) - AdheSe Bond primer (Ivoclar Vivadent, Schaa, Liechenstein) bio je nanesen na caklinu neprekidnim trljanjem 30 sekundi i zatim se višak raspršio i posušio pusterom s komprimiranim zrakom, dok nije nestala pomičnost tekućine. Adheziv AdheSe Bond bio je lagano nanesen i osušen te 10 sekundi polimeriziran svjetlom.

Skupina 7. (Clearfil Protect Bond Skupina) - samojetkajući primer Clearfil Protect Bond (Kuraray, Osaka, Japan) bio je četkicom apliciran na površine dentina i ostavljen stajati 20 sekundi. Nakon što se jetkana površina lagano posušila zrakom, bond je bio nanesen na već jetkani dentin premazan primerom, a zatim se lagano sušio te je 10 sekundi polimeriziran svjetlom.

Skupina 8 (Clearfil Tri-S Bond Skupina) – na sve stijenke kaviteta bio je četkicom apliciran Clearfil Tri-S Bond (Kurray) te ostavljen 20 sekundi. Nakon kondicioniranja površine zuba 20 sekundi, temeljito je bila više od 5 sekundi posušena cijela adhezirajuća površina zrakom pod visokim pritiskom kako bi se bond pretvorio u tanak sloj. Tada se adheziv polimerizirao svjetlom 10 sekundi.

U skupinama od 2. do 8. kaviteti su bili slojevito restaurirani kompozitnom smolom (Renew; Bisco, Schaumburg, IL, SAD). Svaki novi dodatak bio je polimeriziran 40 sekundi polimerizirajcijskom svjetiljkom (Hilux; Benlioglu Dental Inc., Ankara,

Group 2 - This group remained unrestored after MOD cavity preparation.

Group 3 (iBond Group) - The cavities were cleaned and dried. The self-etching, self-priming, bonding adhesive iBond (Heraeus Kulzer, Hanau, Germany) was onto the cavities according to manufacturer’s instructions. Three additional layers of iBond were applied followed by a 30 s waiting time. The surfaces were gently air dried until no movement of the adhesive film was detected (visibly glossy surface) followed by light polymerization for 20 s.

Group 4 (G-Bond Group) - G-Bond (GC Co., Tokyo, Japan) was applied on the cavity surface in accordance with the manufacturer’s instructions. The bonding adhesive was gently dried with an air syringe, followed by light curing for 10 s.

Group 5 (Xeno III Bond Group) - An equal amount of Xeno III Bond (Dentsply/Caulk, Milford, DE, USA) liquid b was dispensed into liquid a and thoroughly mixed for 5 s. The adhesive mixture was applied to the enamel/dentin surfaces and left undisturbed for 20 s. A gentle stream of air was applied to the adhesive for at least 2 s to remove the solvent. The adhesive was then light polmerized for 10 s.

Group 6 (AdheSe Bond Group) - The AdheSe Bond primer (Ivoclar Vivadent, Schaa, Liechtenstein) was applied to enamel with continuous rubbing for 30 s and the excess primer was dispersed and air dried with oil-free compressed air from an air syringe until the mobile liquid film disappeared. The bonding adhesive AdheSe Bond was applied, gently air blown and light cured for 10 s.

Group 7 (Clearfil Protect Bond Group) - The Clearfil Protect Bond (Kuraray, Osaka, Japan) self-etching primer was applied to the dentin surface with a brush and left in place for 20 s. After drying the etched surface with mild air flow, the bonding was applied on the etched-primed dentin, gently air flowed and light-cured for 10 s.

Group 8 (Clearfil Tri-S Bond Group) - Apply Clearfil Tri-S Bond (Kuraray) to the entire cavity wall with a brush tip. Leave it in place for 20 s. After conditioning the tooth surface for 20 s, dry the entire adherent surface sufficiently by blowing high-pressure air for more than 5 s while spreading the bond layer thinly. The adhesive was then light polmerized for 10 s.

From groups 3-8: the cavities were then incrementally restored with a resin composite (Renew; Bisco, Schaumburg, IL, USA). Each increment was cured for 40 s from occlusal surface using a curing

Turska) iz smjera okluzalne površine. Kako bi se standardizirala duljina polimerizacije, vrh svjetiljke postavlja se na okluzalnu površinu zuba. Jakost svjetla bila je barem 500 mw cm^{-2}. Verifikacija izlaznog intenziteta provjeravala se digitalnim mjerilom svjetla dostupnim s polimerizacijskim svjetiljkama za svakih 10 uzoraka.

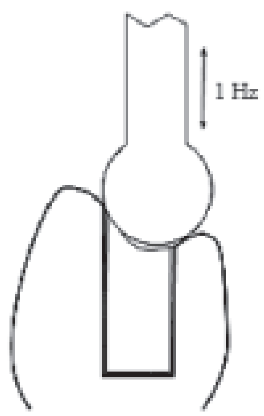
Mehaničko opterećenje

Restaurirani zubi bili su pohranjeni 24 sata u inkubator na temperaturi od 37°C na 24 sata sa 100 % vlažnosti. Tada su svi uzorci 30 sekundi bili obrađivani cikličkom toplinom 500 puta između 5°C i 55°C. Bakreni prsteni - 25 mm u dužini i 10 mm u promjeru - bili su napunjeni samopolimerizirajućom smolom polimetilmetakrilata (Vertex; Dentimex Dental, Zeist, Nizozemska) te su zubi smješteni u smolu do razine CCS-a. Tada su bakreni prsteni sa zubima stavljeni u univerzalni stroj za testiranje (Instron, Canton, MA, SAD). Prečka od nehrđajućeg čelika, 5 mm u promjeru, bila je pričvršćena na gornjem dijelu Istrona i to paralelno prema dužinskoj osi zuba. Gornja etapa bila je postavljena centralno i u razini kontakta s okluzalnom površinom restauracije te bukalne i lingvalne kvržice zuba (Slika 2.). Bila je primijenjena okomita tlačna sila pod brzinom od 1 mm min^{-1}, a sile potrebne za frakturu zuba zapisane su u njutnima.

unit (Hilux; Benlioglu Dental Inc., Ankara, Turkey). To standardize the curing distance, the tip of the polymerization unit was applied to the occlusal surface of the teeth. The intensity of light was at least 500 mw cm^{-2}. Verification of the unit light intensity output was checked with the digital read-out light meter available with the unit every 10 samples.

Mechanical loading

The restored teeth were stored in an incubator at 37 °C in 100% humidity for 24 h. All specimens were thermocycled for 500 times between 5° C and 55 °C using a dwell time of 30 s. Copper rings, 25 mm in length and 10 mm in diameter, were filled with a self-curing polymethylmethacrylate resin (Vertex; Dentimex Dental, Zeist, The Netherlands), and the teeth were placed into the resin to the level of the CEJ. The copper rings with the teeth were then placed into a universal testing machine (Instron, Canton, MA, USA). A 5-mm diameter stainless steel bar was affixed to the upper stage of the Instron. The bar was parallel to the long axis of the teeth. The upper stage was positioned so that the bar was centred over the teeth until the bar just contacted the occlusal surface of the restoration and buccal and lingual cusps of the teeth (Fig 2). A vertical compressive force was applied at a crosshead speed of 1 mm min^{-1} and the force necessary to fracture each tooth was recorded as Newton.



Slika 2. Shematska ilustracija ispitivanja jačine
Figure 2 - Schematic illustration of strength testing.

Statistička analiza

Podaci su statistički analizirani jednosmjernom ANOVA-om i Tukeyevim post-hoc testom. Razina značenja bila je 5 % ($p<0,05$).

Statistical analysis

Statistical analysis of the data was accomplished using one-way ANOVA and Tukey *post-hoc* test. The level of significance was 5% ($p< 0.05$).

Rezultati

Minimalna, maksimalna i srednja vrijednost otpornosti zuba na frakturu (N) te standardna devijacija za svaku od osam eksperimentalnih skupina, prikazane su u Tablici 2.

Results

The minimum, maximum and mean fracture resistance (N) and standard deviation for each of the eight experimental groups are presented in Table 2.

Tablica 2. Minimalna, maksimalna i srednja vrijednost otpornosti zuba na frakturu (N) te standardna devijacija (SD) za svaku od osam skupina

Table 2 Minimum, maximum and mean fracture resistance (N) and the standard deviation (SD) for each of the eight groups.

Grupa • Groups	Kavitet • Cavity	Vrsta restauracije • Restoration Type	Broj • N	Minimum	Maximum	Srednja vrijednost • Mean ± SD
Group 1	Intact	Intact teeth	10	665.00	1049.00	984.00 ± 116.27[a]
Group 2	MOD	Unrestored	10	102.00	250.00	167.30 ± 47.26[b]
Group 3	MOD	iBond	10	602.00	1040.00	872.30 ± 164.99[a]
Group 4	MOD	g-Bond	10	624.00	1050.00	848.70 ± 157.84[a]
Group 5	MOD	xeno III	10	444.00	1049.00	916.30 ± 246.19[a]
Group 6	MOD	Adhese Bond	10	460.00	1043.00	863.20 ± 197.69[a]
Group 7	MOD	Clearfil Protect Bond	10	603.00	1049.00	802.20 ± 183.84[a]
Group 8	MOD	Clearfil Tri-S Bond	10	465.00	1035.00	870.70 ± 126.48[a]
F=26.43, P=0.00, (P<0.05)						

Slična slova označavaju statistički slične vrijednosti (P>0,05) • Similar letters indicate statistically similar values (P>0.05)

Statistička analiza pokazala je da je srednja vrijednost otpornosti zuba na frakturu za skupinu 2. (zubi bez restauracije) bila znatno manja od ostalih (p<0,05). No, nije bilo znatne razlike između intaktnih zuba (Skupina 1.) i ostalih eksperimentalnih skupina (od 3. do 8.).

Rasprava

Restauracija zuba važan je završni dio u liječenju korijenskog kanala. Za uspješnu adhezivnu restauraciju najvažnija je ispravna aplikacija adheziva (13). U praksi samojetkajući adhezivi olakšavaju nanošenje jer smanjuju broj jetkanja. Još je mnogo drugih prednosti koje se mogu navesti u usporedbi s totalnim jetkanjem, kao što su količina vlažnosti nakon što je apliciran na dentin, monomeri smole prodiru do jednake dubine demineralizacije te tako osiguravaju bolju povezanost, a i manji je rizik od postoperativne osjetljivosti (14). Mehanizam samojetkajućih adheziva temelji se na promjeni kemijskog sastava supstrata ili hibridizaciji - površinski sloj dentina djelomice se otapa i rezultanta poroznosti ispunjava se smolom (15). U ovom istraživanju koristile su se dvije vrste samojetkajućih adheziva - preparati koji se apliciraju jedanput (iBond, G-Bond, Xeno III Bond, Clearfil Tri-S Bond), te oni koji se nanose dva puta (Clearfil Protect Bond, AdheSe Bond).

U prijašnjim istraživanjima isticalo se da su otpornost kompozitom restauriranih zuba na frakturu koji su se koristili adhezivnim sustavom, jetkanje cakline i dentina te primjena adheziva, bili približno jednaki intaktnim zubima (16). Dodatno, dentinski adhezivi naneseni na kvržice smanjuju njihovu fleksuru, što smanjuje stres koji se stvara na kruni

Statistical analysis revealed that the mean fracture load for Group 2 (unrestored teeth) was significantly decreased than the rest of the other groups (p<0.05). But, there were no significant differences between the intact teeth (Group 1) and the other experimental groups (Groups 3-8).

Discussion

Restoration of teeth is a critical final step of root canal treatment. Proper adhesive placement is critical process for the success of bonded restorations (13). Self-etch adhesives facilitate application in practice by removing the acid-etching step. There are a number of other advantages that can be listed in comparison to total etching such as the moisture content when applied in dentin, the resin monomers diffuse to the same depth to which the surface was demineralized, thus providing better interlocking, and there is a reduced risk of postoperative sensitivity (14). The bonding mechanism of self etch adhesives is based upon changing the chemical composition of the substrate, commonly referred to as hybridization; the surface layer of dentin/mine is partically dissolved and the resultant porosity filled by resin (15). Two types of self-etch adhesives were used in this study: one was one-step adhesives (iBond, G-Bond, Xeno III Bond, Clearfil Tri-S Bond); the other was two-step adhesives (Clearfil Protect Bond, AdheSe Bond).

Previous research has indicated that the resistance to fractures of composite-restored teeth that utilized adhesive systems enamel-dentin etching and bonding was approximately equal to that of unaltered teeth (16). Additionally, dentin bonding adhesives splint the cusps and reduce cuspal flexure, zuba (17). Mnoga prijašnja istraživanja (9,17) pokazala su da su restauracije s kompozitnom smolom znatno pojačale čvrstoću zuba, posebice ako su jetkani. Naime, jetkanje boji caklinu i dentin te daje dodatnu mehaničku retenciju i dodatnu površinu za dentiniski adheziv te povećava oporavak čvrstoće zuba (18).

Adhezivne restauracije bolje se prenose i dijele funkcionalni stres preko sučelja adhezije za zub koji može pojačati oslabljene strukture (19). U nekim je istraživanjima (9, 20-22) otkriveno da su zubi restaurirani kompozitnom smolom otporniji na frakturu nego oni restaurirani amalgamskim ispunima. Tako je istaknuto da se adhezivni sustav može uspješno koristiti u restauraciji zuba s punjenim kanalom. Trope i njegovi suradnici (16) dokazali su da se otpornost zuba na frakturu jako povećava ako MOD kavitete jetkamo kiselinom prije restauracije kompozitnom smolom. Hurmuzlu i suradnici (10) istaknuli su da su zubi restaurirani kompozitnom smolom bili otporniji na frakturu u usporedbi s onim zubima koji su bili restaurirani amalgamima. U drugim su istraživanjima Hernandez i suradnici te Hurmuzul i njegovi suradnici (11) usporedili otpornost pretkutnjaka s punjenim kanalom na frakturu koje su restaurirali različitim vrstama DA. Otkrili su da su zubi restaurirani s DA otporniji na frakturu. Rezultati ovog istraživanja bili su slični tim istraživanja. Svi ispitani samojetkajući adhezivi pokazali su veću otpornost u usporedbi s kontrolnom skupinom.

U slučaju adhezivnog sustava, čvrstoća veze između materijala i strukture zuba je mikromehanička, drugim riječima, zbog formacije hibridnog sloja (23, 24). Iz devitaliziranog zuba bili su uklonjeni predentin i vlakna kolagena najprije endodontskim instrumentima, a zatim irigacijom NaOCl-a tijekom endodontskog liječenja. Samo ispiranje NaOCl-om dovoljna je da uništi organski dio zaostaloga sloja, ali nije djelotvorna pri uklanjanju cijelog zaostatnog sloja. Korištenje EDTA nakon ispiranja NaOCl-om može rezultirati većom čvrstoćom veze, jer je uklonjen cijeli zaostali sloj (25).

Mnogo navedenih čimbenika djeluje na otpornost zuba na frakturu, uključujući i količinu te lokaciju uklonjenog tkiva (26), veličinu i trajanje opterećenja (1), vrstu zuba te smjer opterećenja i nagib kvržica (26). Dakle, mjera deformacije krune povezana je s uklanjanjem karijesne lezije i ti su postupci preparacije kaviteta važni u operativnoj stomatologiji jer optimalno oblikuju kavitet te utječu na cijelu restauraciju.

which reduces stresses that generate on tooth crowns (17). Several previous studies (9, 17) have shown that restoration with resin composite provided substantial recovery of tooth stiffness, especially when coupled with dentin etching. Etching both enamel and dentin provided additional mechanical retention and additional surface area for the dentin bonding adhesive, enhancing stiffness recovery (18).

Adhesive restorations better transmit and distribute functional stresses across the bonding interface to the tooth with the potential to reinforce weakened tooth structure (19). Some studies (9, 20-22) have found that teeth restored with composite resins were more resistant to fracture than teeth restored with bonded/unbonded amalgam filling materials. They suggested that adhesive systems could be used successfully to restore the root-filled teeth. Trope et al. (16) showed that resistance to fracture of the teeth increased significantly when MOD cavities in the teeth were acid-etched before the restoration with a composite resin. Hurmuzlu et al. (10) reported that teeth restored with packable composite resin had the highest resistance to fracture when compared with amalgam- or ormoser-based composite. In another study, Hernandez et al. and Hurmuzlu et al. (11) compared the resistance to fracture of root-filled premolar teeth restored with different type of DBAs. They found that the teeth restored with DBAs showed more resistance to fracture. The result of this study was similar to these studies. All tested self etch adhesives showed more resistance to fracture up to intact teeth (control group).

In case of adhesive systems, the bond strength between the material and the dental structure is micromechanical, in other words due to formation of a hybrid layer and resin tags (23). The most of the hybrid layer in deep dentin is made up of hybridized resin tags (24). In the devitalized tooth, the predentin and the collagen fibrils are removed first through the action of the endodontic instruments and then through that of NaOCl used as an irrigant during the endodontic treatment. NaOCl irrigation alone is capable of removing the organic potion of the smear layer; it is not effective at removing the entire smear layer. Using EDTA after the NaOCl irrigation might result in higher bond strength because of complete removal of the smear layer (25).

Several factors have been reported to affect the fracture resistance of teeth including: the amount of tissue lost and its location (26), the magnitude and duration of the load (1), tooth type, direction of applied load, slope of the cuspal inclines (26). There-

U ovom istraživanju primijenjena sila iznosila je 1 mm min^{-1}. Espevik (27) je istaknuo da manje brzine prati veća plastična deformacija te će biti zabilježena veća otpornost na frakturu.

Broj susjednih zuba (28), broj okluzalnih kontakta (29), položaj zuba u zubnom luku (30), položaj krune (31), vrsta nosača (32), stanje apeksa (33), propadanje kolagena (34), intermolekularno umrežavanje dentina korijena (35) i vrlo kritično - količina izgubljenog tkiva (36) – sve to utječe na sposobnost zuba s punjenim kanalom da pružaju otpor silama. No, *in vitro* ispitivanja čvrstoće veze mogu i ubuduće ponuditi korisne informacije o promjenama u postupku rada.

U ovom istraživanju ispitivanja su obavljena *in vitro* i provedena 24 sata nakon restauracije. Obavljena je i obrada cikličkom toplinom kako bi se simulirale promjene u vlažnost i temperaturi u ustima. No, da bi se potvrdili rezultati, potrebni su klinički pokusi.

Zaključci

Nakon istraživanja može se zaključiti da:

1. preparacija MOD kaviteta smanjuje otpornost zuba s punjenim kanalom na frakturu;
2. restauracije s kompozitnim smolama znatno povećavaju jačinu potrebnu za frakturu;
3. samojetkajući adhezivi koji se apliciraju jedanput ili dva puta nisu utjecali na otpornost zuba na frakturu.

fore, the measurement of crown deformation associated with caries removal and cavity preparation procedures is important in operative dentistry to optimize cavity designs and subsequent restoration.

In this study, the applying force speed was 1 mm min^{-1}. Espevik (27) stated that lower speeds are accompanied by greater plastic deformation and, thus, higher fracture resistance measurements will be recorded.

In the mouth, the load capability of root filled teeth is influenced by the number of adjacent teeth (28), the number of occlusal contacts (29), tooth position in the dental arch (30), crown placement (31), type of abutment (32), apical status (33), collagen degradation (34), intermolecular cross-linking of the root dentin (35), and crucially by the amount of lost tissue (36). The forces exerted on restorations or teeth are complex in nature. Bond strength tests in vitro are unable to simulate the intraoral forces sufficiently well. However, *in vitro* bond strength tests may still provide useful information on procedural changes.

The present study was carried out *in vitro* and the test was performed 24 h after restorations were placed. Thermocycling was performed to simulate moisture and temperature changes encountered intraorally. However; clinical trials are necesssary to validate the results.

Conclusions

Within the limits of this study, it can be concluded that:

1. MOD cavity preparation reduced fracture resistance of root-filled teeth.
2. Use of composite resin restoration significantly increased the fracture strength.
3. The one-step self etch and two-step self etch adhesives had no influence in the fracture resistance of teeth.

Abstract

Objective: The aim was to study and compare the fracture resistance of root-filled premolar teeth restored with various dentin bonding adhesives (DBAs). **Material and Methods:** Eighty extracted single-rooted human maxillary premolar teeth were randomly assigned to eight groups (n=10). Group 1 (control) did not receive any preparation. From groups 2 to 8, the teeth were root filled and MOD cavities were prepared. Group 2 remained unrestored. Groups 3-8 were restored using the following DBAs: iBond (Heraeus Kulzer), G-Bond (GC Co.), Xeno III (Dentsply/Caulk), AdheSe (Ivoclar Vivadent), Clearfil Protect Bond (Kuraray) and Clearfil Tri-S Bond (Kuraray); all preparations were further restored with a resin composite (Renew, Bisco). All specimens were then stored in 100% humidity at 37 ºC for 24 h, followed by thermal cycling 500 times between 5° and 55 °C. Compressive loading of the teeth was performed by a universal testing machine at a crosshead speed of 1 mm min-1 until failure. The data were recorded in Newton (N) and were submitted to one-way ANOVA and Tukey post-hoc test. **Results:** The mean loads necessary to fracture the samples in each group were: group 1: 984.00 ± 116.27a, group 2: 167.30 ± 47.26b, group 3: 872.30 ± 164.99a, group 4: 848.70 ± 157.84a, group 5: 916.30 ± 246.19a, group 6: 863.20 ± 197.69a, group 7: 802.20 ± 183.84a, group 8: 870.70 ± 126.48a. Similar letters indicate statistically similar values (P>0.05). **Conclusion:** The type of DBAs had no influence on the fracture resistance of teeth.

Received: September 29, 2007
Accepted: February 12, 2008

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Key words
Bicuspid; Tooth Fractures; Root Canal Filling Materials; Dentin-Bonding Agents; Composite Resin

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