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Pouzdanost adhezivnih MOD restauracija na gornjim pretkutnjacima: mikropropusnost i otpornost kvržica na pucanje

Reliability of Bonded MOD Restorations in Maxillary Premolars: Microleakage and Cusp Fracture Resistance

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Sažetak

Svrha: Ovo *in vitro* istraživanje provedeno je na maksilarnim pretkutnjacima kako bi se procijenili mikropropusnost i otpornost kvržica na frakturu. **Materijal i metode:** Uzorci su se sastojali od adhezivno vezanih direktnih ispuna i keramičkih inlaya (ranije pripremljenih umetaka), a ispitani su nakon umjetno simuliranog starenja s pomoću termičkog i okluzalnog cikličkog opterećenja. Za to je uporabljeno 66 tek izvađenih maksilarnih pretkutnjaka, a bilo ih je po šest u svakoj skupini. Zatim su izrađeni standardizirani MOD -kaviteti i podijeljeni u dvije glavne skupine, ovisno o smještaju gingivne stijenke i to jedan milimetar iznad (A1) ili jedan milimetar (A2) ispod cementno-caklinskog spoja (CCS-a). Nakon toga uzorci su podijeljeni u dvije podskupine: Z 250 kompozit za direktno postavljanje i IPS Empress – staklokeramički ispun zatvoren kompozitnim cementom Variolink II. Skupina intaktnih zuba te dvije skupine s prepariranim kavitetima A1 i A2 služile su kao kontrola. Restaurirani zubi uloženi su zatim u blokove od akrilatne smole i stavljeni u stroj za cikličko-termičko i mehaničko opterećenje. Mikropropusnost je procijenjena metodom ocjenjivanja prodora boje pod Zeissovim stereomikroskopom. **Rezultati:** Otpornost kvržica na frakturu ispitana je vertikalnim opterećenjem do pucanja. Srednje vrijednosti testa frakturnog opterećenja i mikropropusnosti analizirane su statistički. Proučavani ispuni nisu pokazali veću razliku u adaptaciji ispuna na caklinskim rubovima. Keramički ispuni bolje su brtvili te snažnije ojačali strukturu zuba nego kompozitni, posebice na necaklinskim rubovima. Priprema kaviteta dosta je oslabila strukturu. **Zaključak:** Ispuni su samo djelomice nadoknadili učinak slabljenja zbog njegove preparacije. Poboljšanje adhezivnih ispuna, tj. adaptacija i pojačanje strukture zuba, stalan su izazov u restaurativnoj dentalnoj medicini.

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Uvod

Napredak u području adhezivne restaurativne dentalne medicine omogućio je da se poboljša rubna cjelovitost i pojačaju preostale oslabljene zubne strukture tako što se rabe različiti adhezivni materijali i restaurativne tehnike. Klinička pouzdanost i dugotrajnost intrakoronarnih adhezivnih ispuna u područjima okluzalnog opterećenja stražnjih zuba uvelike ovisi o njihovoj sposobnosti da izdrže funkcionalno opterećenje i druge čimbenike iz oralnog okoliša, uključujući vlažnost, promjene pH i temperature, te biokemijsku aktivnost bakterija bez loma zuba, ispuna ili odvajanja u području adhezivnog spoja s mikropropusnosti kao posljedicom (1-3).

U nedavnim istraživanjima potvrđeno je da je početna učinkovitost vezanja suvremenih adheziva dosta povoljna bez obzira na korišteni pristup (4), iako je dugoročno u kliničkim uvjetima upitna snaga vezivanja na spoju zuba i ispuna. Usporedba podataka *in vivo* i *in vitro* otkrila je da je najbolja metoda procjene trajnosti adhezije starenje vezanih materija-

Introduction

Recent advances in the field of adhesive restorative dentistry have made it possible to improve the marginal integrity and reinforce the remaining weakened tooth structure by the use of a variety of adhesive materials and restoration techniques.

Clinical reliability and longevity of intracoronal adhesive restorations in stress bearing areas in posterior teeth depend largely on their ability to sustain functional loading and other oral environmental factors including humidity, thermal and pH fluctuations as well as bacterial biochemical activities without fracture of the tooth, restoration or failure in the interfacial adjoining bonds with resultant microleakage (1-3).

Recent investigations have showed that the initial bonding effectiveness of contemporary adhesives is quite favorable regardless of the approach used (4). However, during long term clinical use, the bonding effectiveness of the tooth restoration interfacial joints is questionable.

la bilo na caklini/caklinu ili na dentinu/dentin. U literaturi se ističe da se starenje materijala može postići skladištenjem u vodi i to različito dugo, termičkim cikliranjem, te cikličko-okluzalnim opterećenjem (4). Smatra se da je kritični čimbenik povezan s frakturom krune sve slabija struktura zuba zbog karijesa i nepoduprtog intrakoronarnog ispuna. Tradicionalni metalni ispuni mogu se ponašati kao klin između bukalne i palatinalne kvržice te povećavaju opasnost od njihove frakture (5-7). Teško oštećeni restaurirani zubi, ako se ne primijeni zaštita, u većoj su opasnosti od frakture s nepredvidljivim posljedicama. To je posebice važno kod stražnjih zuba, poput pretkutnjaka, jer njihova anatomija pogoduje ogibanju kvržica i frakturi zbog žvačnoga tlaka. Povećani estetski zahtjevi pridonijeli su sve češćoj kliničkoj primjeni adhezivne tehnologije i proširili mogućnosti estetskih restaurativnih zahvata. Sada kliničari mogu birati različite adhezivne tehnike koje zadovoljavaju i estetiku i učvršćuju zube. Najčešće se adhezivno primjenjuju direktni kompoziti i keramički inlayi. U nekoliko istraživanja potvrđen je učinak pojačanja direktnih kompozitnih ispuna u usporedbi s neadhezivnima (8).

Kompozitni ispuni uporabljaju se od 1960-ih godina kod distalnih zuba u području pod opterećenjem. Ranijim generacijama materijala manjkala je dobra polimerizacijska kontrakcija, boja im je bila nestabilna, a otpornost na trošenje loša, poticali su postoperativnu preosjetljivost, veći je bio otklon kvržica s mogućom frakturom zuba i ponovno se pojavljivao karijes (rekurentni karijes) (4, 5, 9, 10). Ti su problemi u suvremenim kompozitnim materijalima smanjeni na najmanju moguću mjeru primjenom suvremenih adhezivnih tehnika i kompozitnih materijala s većom snagom vezivanja za zubnu strukturu te je postignuta izvrsna otpornost na trošenje i stabilnosti boje. Ostaju problemi polimerizacijske kontrakcije s marginalnim curenjem, mogućnost nakupljanja stresa s posljedičnim ogibanjem antagonističke kvržice i mikropukotine u caklinskoj strukturi, zajedno s teškoćama u stvaranju čvrstoga aproksimalnog kontakta (8-10).

Odgovarajuća polimerizacija kompozitne smole prijeko je potrebna da bi ispuni bili optimalni i biomehanički i fizički. Napetost koja nastaje u postgelacijskoj fazi polimerizacijske kontrakcije može uzrokovati defekte na spoju kompozit –zub te može rezultirati neuspjehom uzrokovanim mikrocurenjem ili nekompenziranom napetošću u zubnoj strukturi s mogućim pucanjem. Unatoč velikom napretku adhezivnih sustava, gotovo nije vjerojatno da bi adhezivni sloj mogao odoljeti polimerizacijskom stresu tijekom svjetlosne polimerizacije kompozitnih smola kod kaviteta bez okolne cakline na cervikalnim rubovima klase kaviteta II i V, čime se povećava problem mikropropusnosti. Osim toga, kompozitne smole imaju viši termički koeficijent ekspanzije i kontrakcije negoli zubna tvar. Slabo vezani spojevi ispuna i kratkoročno i dugoročno podložniji su djelovanju žvačnih sila i oralnom termičkom stresu, te se pojavljuju pukotine u spoju i mikropropusnost (10). Posljednjih godina sve se češće rabe keramički inlayi u područjima jakoga okluzalnog pritiska na stražnjim zubima zahvaljujući poboljšanjima i modernizaciji oblika adhezivnih sustava, smanjenom volumenu kompozitnog materijala koji se uporablja samo za cementiranje te izvrsnim optičkim svojstvima, stabilnosti boje, biokompati-

A correlation of *in vitro* and *in vivo* data revealed that, currently, the most recognized method to assess adhesion durability involves aging of biomaterials bonded to either enamel or dentin. The literature shows that artificial aging has been carried out by storage in water for different periods, thermal cycling and/or occlusal load cycling (4). It has been reported that the most critical factor associated with crown fracture is weakening of tooth structures by caries and large unsupported intracoronal restorations. Traditional metallic restoration may act as a wedge between the buccal and lingual cusps and increase the risk for cuspal fracture (5-7). Severely compromised teeth restored without following protective principles are at greater risk of fracturing, with unpredictable consequences. This is of particular importance for posterior teeth, such as maxillary premolars, because their anatomy favors cusp deflection and fracturing under masticatory stresses. The increasing esthetic concerns added to the expanding clinical implementation of adhesive technology have widened the range of possibilities of adhesive esthetic restorative procedures. A variety of adhesive restorative techniques is now available which would meet the need for esthetics and tooth strengthening effects. Adhesive direct resin composites and ceramic inlays are most frequently used. Several studies have shown the reinforcing effects of adhesive direct resin composite restoration when compared to non-adhesive restorations (8).

Resin composite has been used in stress bearing locations in posterior teeth since the1960s. The earlier generations of this material showed problems of polymerization shrinkage, colour instability, poor wear resistance, post restoration hypersensitivity, greater cuspal flexure with possible tooth cracking and recurrent caries (4, 5, 9, 10).

Currently, these problems have been minimized by the introduction of recent adhesive technologies and resin composite materials with greater bond strength to tooth structure, superior wear resistance and color stability of resin composite. Nevertheless, the problem of polymerization shrinkage with marginal leakage remains as well as the possibility of buildup of stresses with consequent deflection of the opposing cusps and micro-cracks in enamel structure together with difficulty in building up of tight proximal contacts (8-10).

Adequate polymerization of resin composite is essential for optimal quality restoration both biomechanically and physically. However, stresses arising from post-gel polymerization shrinkage may produce defects in the resin composite-tooth bonds, leading to failure associated with microleakage or induce intolerable stresses in tooth structure with possible cracking. Despite all advances with adhesive systems, it is widely known that the adhesive interface is less likely to resist the polymerization stresses arisen during light curing of composite resins in enamel-free cavity margins such as the cervical margins of class II and V cavities, where the problem of microleakage is magnified. Furthermore, resin composite has a markedly higher thermal coefficient of expansion and contraction than that of the tooth structure. Weakly bonded tooth restoration interfaces are more prone to the effects of the masticatory forces and oral thermal stress in the short and long term period leading to interfacial gaps and microbilnosti, otpornosti na biodegradaciju i čvrstoći keramičkih materijala koji su nedavno ponuđeni kao alternative tradicionalnoj feldspat-keramici (5, 11). Svrha ovog istraživanja bila je istražiti mikropropusnost i otpornost kvržica na frakturu kod adhezivnih MOD-kaviteta s direktnim kompozitom u usporedbi s keramičkim inlayima nakon umjetnog starenja potaknutog termičkim i mehaničkim cikliranjem pod opterećenjem.

Materijali i metode

U ovom istraživanju korišteno je tek izvađenih 66 maksilarnih pretkutnjaka iz ortodontskih razloga i podijeljenih u skupine po 6 zuba. Odabrani su samo oni koji nisu imali karijes, pukotine ili razvojne anomalije.

Svaki je zub bio koronarno prekriven voskom i to dva milimetra ispod caklinsko-cementnog spoja (CCS-a) te uložen u gumastu smolu (Anti-Rutsch-Lack, Wenko-Wenselaar, Hilden, Njemačka). Nakon sušenja višak smole apikalno je uklonjen lancetom kako bi se dobila ujednačena debljina gumaste smjese od oko 0,25 milimetara da simuliraju parodontni ligament. Zubi su nakon toga okomito uloženi u blokove od samostvrdnjavajuće akrilatne smole i to dva milimetra ispod CCS-a. Kod 60 pretkutnjaka preparirani su MOD-kaviteti. Ti su zubi zatim podijeljeni u dvije glavne skupine, ovisno o pružanju cervikalnog ruba kaviteta. Kod skupine A1 cervikalni rub (mezijalno i distalno) bio je jedan milimetar iznad CCS-a, a kod A2 cervikalni rubovi (mezijalno i distalno) bili su jedan milimetar ispod CCS-a. Kaviteti su preparirani tako da im je bukopalatinalna dimenzija na okluzalnom rubu iznosila 50 posto udaljenosti među zubnim kvržicama. Mjerenje je obavljeno digitalnom pomičnom mjerkom (Mettler Toledo Inc., Columbus, OH, SAD) s točnošću od 0,01 milimetar. Rub kaviteta bio je prije preparacije označen olovkom. Dubina kaviteta bila je jedan milimetar ispod caklinsko-dentinskog spoja. Bukalni i palatinalni zidovi preparacije okluzalno su divergirali pod kutom od oko 15 stupnjeva. Svi rubovi kaviteta bili su zakošeni. Kako bi se dobio prolaz kroz caklinu, korišteno je okruglo svrdlo veličine 1 (Dental Burs, DB, Chicago, Illinois, SAD). Za završetak preparacije i zaobljavanje unutarnjih kutova uporabljeno je konično dijamantno svrdlo sa zaobljenim vrškom (Dental Burs, DB, Chicago, Illinois, SAD). Preparacije su rađene zračnom turbinom s velikim ubrzanjem i novim svrdlom te obilno hlađene vodenim sprejem. Zbog standardizacije je nagib stijenki kaviteta podešen posebnim mjeračem (Degudent/Dentsply, Hanau-Wolfgang, Njemačka) pri niskim okretajima i korištenjem vanjskoga vodenog hlađenja.

Prethodne dvije skupine ponovno su podijeljene u dvije podskupine, ovisno o korištenom materijalu za ispune. U skupini B1 rabljen je jednobojni Z 250 (mikrohibridni kompozit 3M-ESPE, St. Paul, MN, SAD) za ispunjavanje kaviteta nakon „*total etch*" adhezivnog pristupa i Single Bond Primer/

leakage (10). The use of ceramic inlays in stress bearing locations in posterior teeth has recently increased because of the improvements in modern formulations of adhesive systems, the reduced volume of resin composite which is used only as a cementing agent in addition to the superior optical properties, color stability, biocompatibility, resistance to biodegradation and superior strength properties of the ceramic material that have been recently introduced as alternatives to the traditional feldspathic porcelain (5,11). The objectives of this study were to investigate microleakage and cusp fracture resistance of bonded MOD direct resin composite versus ceramic inlays after artificial aging by thermal and occlusal load cycling.

Materials and methods

66 maxillary premolars which were freshly extracted for orthodontic purposes were used in this study with 6 premolars for each study group. Only the teeth which were free of caries and showed no cracks or developmental defects were selected.

Each tooth was covered coronally with wax up to a level of 2 mm below the cemento-enamel junction (CEJ) and then dipped once in gum resin (Anti-Rutsch-Lack, Wenko-Wenselaar, Hilden, Germany). After the gum resin dried, excess resin was trimmed apically with a lancet to make a uniform thickness of gum resin of about 0.25 mm to simulate the periodontal ligament. The teeth were then immersed vertically in self-curing acrylic blocks in a vertical direction to a level of 2 mm below the cemento-enamel junction. MOD cavities were prepared on 60 premolars. The teeth with prepared cavities were classified into two main groups according to the extension of the cervical margin of the cavities. In group A1, the cervical margins (mesially and distally) were located 1 mm above the CEJ, while in group A2 the cervical margins (mesially and distally) were located 1 mm below. Cavities were prepared so that the measured buccolingual dimensions at the occlusal cavity margins were one half of the intercuspal distance (distance from one cusp tip to the other). Measuring was performed using a digital caliper (Mettler Toledo Inc., Columbus, OH, USA) with an accuracy of 0.01 mm. The cavity outline was marked on the tooth before preparation using a pencil. The cavity depth was 1 mm below the dentino-enamel junction. The buccal and lingual walls of the preparation were done with an occlusal divergence of about 15° degrees angle. The two proximal axial walls converged occlusally with about 15° degrees angle. All cavity margins were connected by butt joints. A round bur size 1 (Dental Burs, DB, Chicago, Illinois, USA) was used for gaining access through enamel. A tapered cylindrical diamond stone with a round end (Dental Burs, DB, Chicago, Illinois, USA) was used to complete the preparation producing rounded internal line angles. The preparations were performed using air-turbine of high speed ranges under abundant air-water spray using new burs for each 5 cavities. For standardization purposes, the walls inclinations were adjusted with the use of a surveyor (Degudent/Dentsply, Hanau-Wolfgang, Germany) at low speed ranges using an external adheziva (3M ESPE, St. Paul, MN, SAD). U skupini B2 postavljeni su keramički inlayi (IPS impress, Ivoclar Vivadent, Schaan, Lictenstein) te cementirani Variolinkom II (Ivoclar Vivadent), dvostruko stvrdnjavajućim kompozitnim cementom. Pri izradi uzoraka iz skupine B1 cijeli kavitet jetkan je 30 sekundi 35-postotnom ortofosfornom kiselinom (Ivoclar Vivadent, Schaan, Lictenstein), zatim 10 sekundi ispiran vodom te posušen odmašćenim i suhim komprimiranim zrakom. Kako bi se produžilo vrijeme aplikacije adhezivnog sustava i poboljšala stabilnost veze, prema preporukama Reisa i njegovih suradnika (12), mikročetkicom su nanesena dva sloja Single Bonda (primer/adheziv, 3M ESPE) sušena pet sekundi odmašćenim i suhim komprimiranim zrakom kako bi se isparila otapala, te polimerizirana 20 sekundi svjetiljkom za polimerizaciju (XL2500 3M-ESPE, St. Paul, MN, SAD) koja emitira svjetlo jakosti 580 mW/cm^2. Postavljena je Mylnarova matrica s nosačem na zub. Zatim je kompozit Z 250 (3M –ESPE) postupno stavljen u kavitet. Najprije su napunjeni aproksimalni dijelovi te svjetlosno polimerizirani tako da je polimerizacijski vrh bio usmjeren iz gingivnog smjera, a ostali dijelovi polimerizirani su iz okluzalnog smjera. Debljina svakog sloja bila je oko dva milimetra i polimerizirana je 40 sekundi. Svi su ispuni na kraju obrađeni bijelim kamenčićima (Dental Burs, DB, Chicago, Illinois, SAD) te diskovima za poliranje (Soflex discs, XT, 3M-ESPE) pri niskim okretajima i uz vodeno hlađenje. Pri izradi ispuna u skupini B2 uzet je otisak od polivinil-siloksana (Express, 3M ESPE, St. Paul, MN, USA) i zatim su izrađeni sadreni master-modeli (BeGo Stone Plus, BeGo, Bremen, Njemačka) za svaki uzorak. Inlayi su bili prema uputama proizvođača izrađeni od pojačane staklokeramike IPS Empress (Ivoclar Vivadent, Schaan, Lichtenstein) tehnikom toplog prešanja. Njihove spojne površine pjeskarene su česticama aluminijeva oksida od 50 µm i pritiskom od 87 psi-a (ili funti- težina) u pjeskari (KaVo, Biberach, Njemačka). Spojne površine zatim su jednu minutu jetkane 10-postotnom hidrofloričnom kiselinom (Ivoclar-Vivadent, Schaan, Lichtenstein) te isprane vodom i posušene odmašćenim i suhim komprimiranim zrakom, a površine su silanizirane Monobondom S (Ivoclar-Vivadent, Schaan, Lichtenstein) nanesenim 60 sekundi te posušene također odmašćenim i suhim komprimiranim zrakom. Kaviteti su pripremljeni slično kao i u skupini prije toga, ali je nakon jetkanja svih stijenki primijenjen Excite primer/adheziv (Ivoclar, Vivadent, Schaan, Lichtenstein). Prianjajuće površine inlaya pokrivene su niskoviskoznom smolom (Heliobond, Ivoclar, Vivadent, Schaan, Lichtenstein) ravnomjerno raspoređenom u tankom sloju zrakom, ali nepolimeriziranom. Na priljubne površine inlaya nanesen je kompozitni cement Variolink II (Ivoclar Vivadent, Schaan, Lichtenstein) zamiješan prema uputama proizvođača. Inlayi su postavljeni u kavitete, a višak cementa uklonjen je sondom uz konstantni lagani pritisak kuglastim nabijačem. Svjetlosna polimerizacija obavljena je sa svake strane po 40 sekundi svjetiljkom XL2500 3M-ESPE. Za svako testiranje mikrocurenja i frakturne otpornosti kvržica koristila su se dvadeset i četiri uzorka. Kao kontrolna skupina služilo je šest pretkutnjaka podvrgnutih testu frakturne otpornosti. Prva kontrolna skupina (C) sastojala se od intaktnih maksilarnih pretkutnjaka bez ikakvih

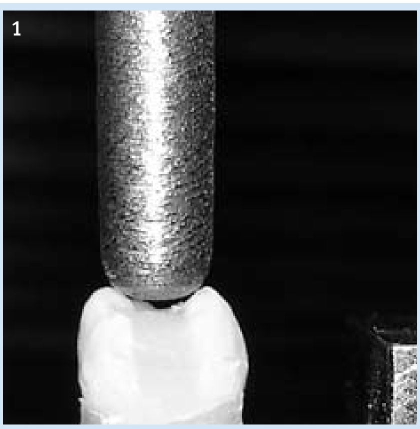
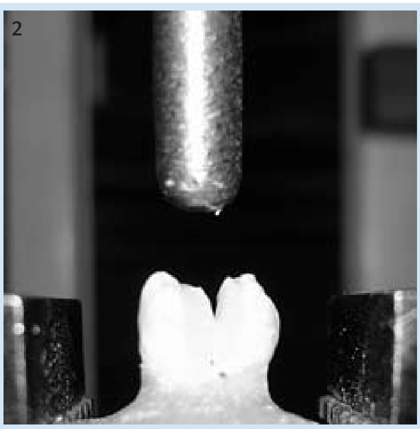
water coolant. The previous two groups were again subdivided into two subgroups according to the restorative material used. In group B1, Z250 (a micro-hybrid composite resin, 3M-ESPE, St. Paul, MN, USA) was used for filling the cavities using the same shade following the total-etch approach using the Single Bond Primer/adhesive(3M ESPE, St. Paul, MN, USA). In group B2, ceramic inlays (IPS impress, Ivoclar Vivadent, Schaan, Lictenstein) were cemented using Variolink II (Ivoclar Vivadent) Dual cure composite resin. In production of group B1 samples, the entire cavity preparation was etched for 30 seconds with 35% orthophosphoric acid (Ivoclar Vivadent, Schaan, Lichtenstein) followed by water rinsing for 10 seconds and air drying for 5 seconds with oil and water free compressed air. In order to prolong the application time of the resin adhesive so as to improve bond stability as reported by Reis et al (12), two successive applications of Single Bond (primer/adhesive, 3M ESPE) were placed on the preparation by a microbrush, air thinned for 5 seconds with oil and water free compressed air to evaporate the solvent, followed by light curing for 20 seconds with a light curing unit (XL2500 3M-ESPE, St. Paul, MN, USA) that provides a light intensity of 580 mW/cm^2. A Mylar matrix strip tied to a toffelmire matrix retainer was then applied to the tooth. Z250 resin composite (3M –ESPE) was then incrementally applied to the cavity. The proximo-gingival parts were filled first and light cured so that the light curing tip was directed from the gingival direction while the following increments were cured from an occlusal direction. The thickness of each increment was about 2 mm and was cured for 40 seconds. All restorations were finished with white stones (Dental Burs, DB, Chicago, Illinois, USA) and finishing discs (Soflex discs, XT, 3M-ESPE) at low speed with water coolant. In production of B2 samples after cavity preparation, a polyvinyl siloxane impression (Express, 3M ESPE, St. Paul, MN, USA) was taken in order to produce a hard stone master model (BeGo Stone Plus, BeGo, Bremen, Germany) for each sample. Reinforced glass-ceramic IPS Empress (Ivoclar Vivadent, Schaan, Lichtenstein) inlays were fabricated by the heat-pressing technique according to the instructions of the manufacturer. The fitting surfaces of the inlays were sandblasted with aluminum oxide particles of 50 µm at a pressure of 87psi in a sandblasting machine (KaVo, Biberach, Germany). The fitting surfaces were then etched with 10% hydrofluoric acid (Ivoclar-Vivadent, Schaan, Lichtenstein) for 1 minute followed by rinsing with water and dried with oil and water free compressed air. The fitting surfaces were then silanized with Monobond S (Ivoclar-Vivadent, Schaan, Lichtenstein) applied for 60 seconds and air dried. The prepared cavities were treated similarly to the previous group but with the application of Excite primer/adhesive (Ivoclar, Vivadent, Schaan, Lichtenstein) following phosphoric acid etching of the entire cavity walls. The fitting surface of the inlay was then covered by a layer of bonding agent (Heliobond, Ivoclar, Vivadent, Schaan, Lichtenstein), which was air-thinned but not light cured. The dual cure resin cement VariolinkII (IvoclarVivadent, Schaan, Lichtenstein) was then mixed according to the instructions of the manufacturer and applied to the fitting surface of the kaviteta. U drugoj kontrolnoj skupini (C2) preparirani su MOD-kaviteti na isti način kao i u skupini A1, tretirani su, ali ostavljeni bez ispuna. U trećoj kontrolnoj skupini (C3) u zubima su preparirani MOD-kaviteti slično kao u A2 skupini, ali bez tretiranja i postavljanja ispuna. Testne skupine postavljene su u odvojene vrećice i termociklirane zajedno u 2000 ciklusa u vodenoj kupelji između 5±2° i 55±2°, uz zadržavanje od 30 sekundi u svakoj kupki i vremenu transfera od 15 sekundi. Zubi su zatim postavljeni u kompjutorski kontrolirani uređaj za testiranje (model LRX-Plus, Lloyed inst. Ltd, Fareham, Velika Britanija) koji je proizvodio naizmjeničnu vertikalnu silu između 25 i 100 njutna pri 20 ciklusa/minuti (20 Hz) u trajanju od 500 ciklusa. Za prijenos opterećenja uporabljena je čelična šipka promjera šest milimetara tako da je istodobno dodirivala obje kvržice na unutarnjim padinama bez doticaja ispuna (slika 1.). U testu otpornosti na frakturu, zubi su podvrgnuti vertikalnom pritisku na istom uređaju (LRX-Plus) i istom čeličnom šipkom, ali je opterećenje bilo konstantno i postupno je raslo 0,5 milimetara u minuti sve do točke pucanja zuba. Zabilježene su dobivene vrijednosti snage u njutnima (N) za pucanje kvržica, izračunata je srednja vrijednost te korištena za statističku analizu (slika 2.). Za procjenu mikropropusnosti zubi su obojeni dva puta uzastopce prozirnim lakom za nokte, osim ispuna i jednog milimetra apikalno od cervikalnih rubova. Uzorci su uronjeni u metilnu otopinu plave boje (1 gram boje otopljen u 100 mililitara destilirane vode). Nakon toga su oprani i osušeni komprimiranim zrakom te rezani uzdužno u meziodistalnom smjeru dijamantnom pilom (Isomet, Buehler, Lake Bluff, IL, SAD) (0 do 300 RPM-a fiksno) uz vodeno hlađenje. Zubi su pregledani streomikroskopom (Zeiss, Göttingen, Njemačka) pri povećanju od 40 puta kako bi se ustanovio stupanj penetracije boje kroz gingivne rubove ispuna mezijalno i distalno.

Prodor boje stupnjevan je prema sljedećim kriterijima:
0 = nema prodora boje
1 = prodor boje do sredine gingivne stijenke
2 = prodor boje dalje od sredine gingivne stijenke
3 = prodor boje dopire do aksijalnih stijenki
4 = prodor boje kroz dentinske tubule

Kod frakturne otpornosti primijenila se analiza varijance (ANOVA) za usporedbu dobivenih srednjih vrijednosti opterećenja. Za određivanje vrijednosti statističke značajno-

inlay. The inlays were then inserted into the cavities; excess cement was removed with a dental probe while maintaining light pressure on the inlay with a ball burnisher. Light curing was then carried out from each side of the restoration for 40 seconds using XL2500 3M-ESPE curing unit. Twenty-four of such prepared specimens were used for each of the study tests, microleakage and cusp fracture resistance. Three groups of 6 premolars each were subjected to the cusp fracture resistance test as control groups. The first control group (C) was in the form of intact maxillary premolar teeth without any cavity preparation. In the second control group (C1), MOD cavities were prepared in a similar manner as in group A1 without any treatment or restoration. In the third control group (C2), MOD cavities were prepared in a similar manner as in group A2 without any treatment or restoration. The test groups were placed in separate mish bags and thermocycled together for 2000 cycles in water baths between 5±2° and 55±2° with dwell time of 30 seconds in each bath and a transfer time of 15 seconds between baths. The teeth were then loaded in a computer controlled universal testing machine (model LRX-Plus, Lloyed inst. Ltd, Fareham, UK) which delivered an intermittent vertical force between 25-100 N at 20 cycle/minute (20HZ) lasting 500 cycles. A steel rod with a rounded end of 6mm diameter was used to deliver loading while touching the buccal and lingual cusps simultaneously at their internal inclines without touching the restoration (Figure 1). In cusp fracture resistance test, the teeth were subjected to vertical compression testing using the same universal testing machine (model LRX-Plus), steel rod and loading style delivered static, gradually increased loading at a speed of 0.5mm/min until a failure point. The value of the force in Newton (N) required to produce cusp fracture was determined as well as the mean value and it was calculated and used for statistical analysis (Figure 2).

In assessing microleakage, the teeth were painted with two successive layers of clear nail varnish except the restorations and 1 mm apical to their cervical margins. The specimens were then immersed for 8 hours in methylene blue die solution prepared by dissolving 1 g of the dye in 100ml distilled water. The specimens were then removed from the dye, washed and dried with compressed air and then sectioned longitudinally in a mesiodistal direction with a diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) that can

1

2


Slika 1. Okluzalno cikličko opterećenje
Figure 1 Occlusal load cycling
Slika 2. Uklonjen teret nakon frakture
Figure 2 Unloading after fracture

sti uporabljen je Tukeyev post-hoc test tada kada je ANOVA upozorila na statistički znatnu razliku. Razina statističke značajnosti postavljena je na p≤0,05. Za testiranje mikropropusnosti rezultati bojenja statistički su procijenjeni Kruskal-Wallisovim neparametrijskim testom NOVA s razinom značajnosti postavljenom na p≤ 0,05. Statistička analiza obavljena je SPSS-om ® (statistički paket za znanstvena ispitivanja) za Windowse ™ (Microsoft, Kalifornija, SAD).

provide 0-300 rpm fixed to one speed using water coolant. The teeth were then examined for the degree of dye penetration through the gingival margins of the restorations both mesially and distally using Stereo-microscope (Zeiss, Göttingen, Germany) and evaluated for the degree of dye penetration using a fixed magnification of x 40.

Dye penetration was graded according to the following scoring system:

0 = No dye penetration
1 = dye penetration to the middle of the gingival wall
2 = dye penetration beyond the middle of the gingival wall
3 = dye penetration reaching the axial wall
4 = dye penetration through the dentinal tubules

For cusp fracture resistance, analysis of Variance (ANOVA) test was used to compare fracture load means. Tukey's post-hoc test was used to determine significant differences between means when ANOVA test renders a statistically significant difference. The significance level was set at P ≤ 0.05.

In microleakage testing, the results of the staining measurements were statistically evaluated using Kruskal-Wallis Non-Parametric ANOVA with a level of significance at p ≤ 0.05. Statistical analysis was performed with SPSS 13.0® (Statistical Package for Scientific Studies) for Windows.

Rezultati

Ni u jednoj skupini nije bilo potpuno spriječena propusnost. U tablici 1. nalaze se vrijednosti frekvencije za ocjene prodora boje kod različitih skupina. Kod keramičkih inlaya (B2) rubovi cakline manje su popuštali, pa se propusnost pojavljivala manje negoli kod kompozitnih ispuna, ali bez statistički značajne razlike (p=0,483). Sva istraživanja pokazala su propadanje u prianjanju ispuna kad su cervikalni rubovi bili apikalno od CCS-a. Propadanje cjelovitosti veze bilo je statistički značajno u skupini B1 (P=0,038), a nije bilo značajno u skupini B2 (0,05<P). Kod rubova bez cakline kera-

Results

None of the test groups could totally prevent leakage. The frequencies of different scores of dye penetration for the different study groups are presented in Table 1. At enamel margins, ceramic inlay restorations (B2 group) showed less leakage than resin composite (B1 group) restorations with no statistical significance (P= 0.483). All studied groups showed deterioration of adaptation when the cervical margins were located apically to the CEJ. This deterioration was statistically significant for B1 group (P=0.038) and insignificant for B2 group (0.05 <P). At non-enamel margins, ceramic in-

Tablica 1. Vrijednosti mikropropusnosti
Table 1 Microleakage scores

Rezultat • Score	Bod 0 • Score 0	Bod 1 • Score 1	Bod 2 • Score 2	Bod 3 • Score 3	Bod 4 • Score 4
A1B1[a]	5	2	2	2	1
A1B2[a]	7	4	1	0	0
A2B1[b]	1	1	3	3	4
A2B2[a]	5	4	2	1	0

Razina statističke značajnosti p ≤ 0,05 - različita slova upućuju na statistički značajne razlike • Significance level at P ≤ 0.05; different letters indicate significant differences

Tablica 2. Srednje vrijednosti frakturnog opterećenja svih skupina
Table 2 Mean fracture loads (N) of all study groups

Skupina • Group	A. sredina • Mean	f-vrijednost • f-value	p-vrijednost • P-value
A1B1	797.3 c		
A1B2	817.9 c		
A2B1	723.7 b		
A2B2	780.6 c		
C	1261.1 g		
C1	492.3 a	428.048	<0.001*
C2	455.0 a		

Razina statističke značajnosti p ≤ 0,05, različita slova upućuju na statistički značajne razlike • Significant at P ≤ 0.05; different letters indicate significant differences mički inlayi (B2) mnogo su bolje prianjali nego kompozitni ispuni (B1) (p=0,03).

U tablici 2. prikazane su srednje vrijednosti opterećenja potrebnog za frakturu.

Tukeyev test pokazao je da su skupine C2 i C1 (skupine bez ispuna) statistički mnogo manje otporne na frakturu (p< 0,01), bez velike razlike među njima. Između restauriranih uzoraka nije bilo statistički značajne razlike u frakturnoj otpornosti zbog različitih preparacija na caklinskom rubu (0,05<P). Zabilježene su samo nešto više vrijednosti frakturne otpornosti kod keramičkih inlaya (B2) u odnosu prema kompozitnim ispunima (B1), ali bez statistički značajne razlike. U skupini uzoraka B2, u kojoj rubovi preparacije nisu bili u caklini, zabilježena je statistički značajno niža frakturna otpornost na opterećenje nego kod uzoraka u B1 (p< 0,05). Intaktni zubi u skupini C imali su statistički veću srednju vrijednost frakturne otpornosti od svih ispitivanih skupina (p<0,05).

Rasprava

Pouzdanost bilo kojeg adhezivnog ispuna u osnovi ovisi o sposobnosti ostvarivanja i održavanju optimalne kvalitete te trajnosti i cjelovitosti prianjanja. Trajna i pouzdana veza između ispuna i preostalih stijenki kaviteta treba ravnomjerno zabrtviti spoj kako ne bi bilo mikropropusnost fluida, molekularnih gibanja, ulaska bakterija i hrane koji mogu rezultirati postoperacijskom osjetljivošću, rubnim obojenjem, ponovnim karijesom i štetnim utjecajem na pulpu. Osim toga trebala bi pojačati strukturu zuba dobrim križnim povezivanjem prekinutih zubnih struktura i učinkovito prenositi i ravnomjerno rasporediti reakcijski stres u restauriranom kompleksu sastavljenom od ispuna, zubne strukture i spojnog sloja među njima (13, 14).

Rezultati ovog istraživanja pokazali su da je mikropropusnost na gingivnim rubovima tretiranih uzoraka statistički značajno veće kod rubova bez cakline i kompozitnih ispuna. Takvo popuštanje brtvljenja nije bilo značajno jedino kod keramičkih restauracija. Ti se rezultati slažu s već objavljenim istraživanjima te govore u prilog tvrdnji da ispuni II. razreda, kada su im gingivni rubovi ispod CCS-a, rubno popuštaju na tom dijelu (14, 15). Rezultati ovog istraživanja pokazali su da ni kod jedne skupine nije bilo moguće u cijelosti spriječiti mikropropusnost na gingivnoj stijenki, što se slaže s istraživanjem Erdileka i suradnika (15) koji su zaključili da je gingivna mikropropusnost i dalje klinički problem unatoč novim adhezivnim sredstvima. Istaknuli su da je kombinirano korištenje termičkog i mehaničkog cikliranja odlučujuće u procjeni gingivne mikropropusnosti kod adhezivnih ispuna II. razreda.

Mikropropusnost je povezana s nekoliko čimbenika, poput dimenzijske promjene materijala zbog polimerizacijske i termičke kontrakcije, upijanja vode, mehaničkog stresa i dimenzijske promjene zubne strukture (16). Polimerizacijska kontrakcija kompozitnih materijala na bazi smole može stvoriti kontrakcijske sile i oštetiti vezu s kavitetnim stijenkama, rubnu pukotinu i posljedično mikropropusnost (16). Moder-

lay (B2 group) restorations could provide significantly better adaptation than resin composite (B1 group) restorations (P=0.03).

The fracture load means are presented in Table 2.

Tukey's test results showed that groups C2 and C1 (unrestored groups) showed statistically significantly lowest fracture strength ($P < 0.001$) with no statistically significant difference between these two groups. Among the restored groups of specimens, there was no statistically significant difference in fracture resistance strength due to different preparations at enamel margins (0.05 < P). Only statistically insignificantly higher values of fracture resistance strength for the ceramic inlay (group B2) compared to the composite resin (group B1) were recorded. However, in a group of specimens where margins of preparations were not placed in enamel, specimens group B2 showed statistically significant higher fracture load mean value than group B1 (P< 0.05). Intact teeth, specimen group C, showed statistically significantly highest fracture load mean values of all study groups (P< 0.05).

Discussion

The reliability of any adhesively bonded restoration is basically dependent on its ability to establish and maintain optimum quality of a durable wall-to-wall integrity. A durable and reliable bond between the restoration and the remaining tooth structure should be able to uniformly seal interfaces against miroleakage of fluids, molecular movements, ingresses of bacteria and nutrients which may lead to post-restoration hypersensitivity, marginal discoloration, recurrent caries and adverse pulpal consequences. Furthermore, it should be able to reinforce the remaining tooth structure by effectively cross- linking the discontinuity of the tooth structure and efficiently transfer and distribute functional reactionary stresses throughout the restorative complex which is formed up of the remaining tooth structure, the restoration and the adjoining bonds (13, 14).

The results of this investigation showed that microleakage at the gingival margins of the test specimens was significantly greater at the non- enamel margins of resin composite restorations. However, such deterioration in sealing ability was only insignificant for ceramic restorations.

This is in agreement with previous investigations indicating the deterioration of adaptation at the cervical margins of class II restorations when it is located below the cemento-enamel junction (14, 15).

The results of this investigation showed that none of the test groups could totally prevent microleakage at the restoration gingival margin. This is in agreement with the study of Erdilek et al. (15) who concluded that gingival microleakage still remains to be a clinical problem even with newly developed adhesive systems. They showed that the combined use of thermocycling and load cycling was a decisive factor in assessing the gingival microleakage in Class II adhesive restorations.

Microleakage is related to several factors, such as dimensional changes of materials due to shrinkage of materials' polymerization, thermal contraction, absorption of wa-ni kompoziti volumno kontrahiraju od 2,6 do 4,8 posto, a čak ni moderni adhezivni sustavi koji stvaraju snažne veze jače od 20 megapascala, koje su čak snažnije od sila kontrakcije (13-17 MPa), ponekad ne mogu podnijeti ukupna naprezanja te počinje odvajanje i pojavljuju se otvoreni rubovi (16). Oblik kaviteta također može utjecati na prianjanje, točnije „faktor C" kaviteta dokazano je povezan s mikropropusnošću, posebice ako su ispunjeni kompozitnim materijalom i dentinskim adhezivom (16). Jedna od najslabijih točaka kompozitnih ispuna II. razreda jest gingivna stijenka aproksimalnog kaviteta kod koje, ako nema cakline za vezivanje, ostaje manje stabilan supstrat poput cementa i dentina. To je potvrdio Fabianelli (2004.) te izvijestio o prisutnosti vanjskog sloja, djelomice stvorenog od cementa, od 150 do 200 μm ispod CCS-a koji ne dopušta mikroretenciju adhezivnim materijalima (16). Smjer pružanja dentinskih tubula može negativno utjecati na kvalitetu hibridizacije i pogoduje propuštanju ispuna na osnovi smola ako se postavljaju u dublje aproksimalne kavitete (16). Rezultati ovog istraživanja pokazali su da adhezivno cementirani keramički inlayi mogu znatno smanjiti rubno popuštanje u odnosu prema direktnim kompozitnim ispunima, posebice ako su rubovi bez cakline.

Sve ovo može se sažeti u dvije osnovne točke:

1. glavna prednost keramičkih inlaya u odnosu prema direktnim kompozitnim ispunima kod velikih kaviteta II. razreda jest u ograničenom malom volumenu kontrahirajuće smole koja se rabi za cementiranje;
2. koeficijent termičke ekspanzije i kontrakcije keramike blizak je koeficijentima zubnih struktura, a kompozitni materijali znatno se više skupljaju i šire pri grijanju i hlađenju.

Zato se može očekivati da adhezivno cementirani keramički ispuni bolje brtve gingivne rubove, posebice ako nema cakline, no vjerojatnost stvaranja snažnih veza nije velika. Na sličan su način Neil i suradnici (2005.) (17) pronašli da su indirektni kompozit Solidex i keramički sustav Vitadur postavljeni kao inlayi, bolje brtvili na cervikalnim rubovima MOD-kaviteta II. razreda, nego kompozitni materijal Charisma postavljen direktnom i indirektnom metodom. U njihovim istraživanjima gingivni rubovi postavljeni su jedan milimetar ispod cementno-caklinskog spoja (CCS-a).

Uludag i suradnici (2009.) (18) proučavali su mikropropusnost keramičkih inlaya cementiranih različitim kompozitnim cementima i sustav dentinskih adheziva metodom prodora boje na caklinskim i dentinskim rubovima. Pronašli su da je ukupno mikropropusnost na caklinskim rubovima bila mnoga manja nego na rubovima bez cakline.

Kod zdravih stražnjih zuba bukalne i lingvalne kvržice povezane su okluzalnom caklinom i marginalnim grebenom. Kad se ti povezni elementi žrtvuju tijekom preparacije kaviteta, kvržice se lakše deformiraju i razdvajaju pod pritiskom okluzalnih sila te postaju sklonije frakturama (1, 2).

U dosadašnjim studijama također je testirana frakturna otpornost kvržica adhezivno restauriranih zuba (5, 6), a u ovom je istraživanju područje interesa bilo dugoročno ponašanje dvaju adhezivnih materijala za restauraciju - keramike i direktnog kompozita. Restaurirani uzorci najprije su bili izloženi termičkom i mehaničkom cikličkom opterećenju, a

ter, mechanical stress and also dimensional changes in tooth structures (16). The polymerization shrinkage of a resin-based composite can create contraction forces that may disrupt the bond to cavity walls, with marginal failure and subsequent microleakage (16). Modern composites undergo volumetric contractions ranging between 2.6% and 4.8 % and even if modern dentin bonding agents exhibit bond strengths to dentin higher than 20 MPa, exceeding the contraction stress generated by polymerisation stress (13-17 MPa), total contraction forces may win the adhesive strength to substrates, leading to open margins (16).

The shape of the cavity can also challenge the adaptation: in fact, the C factor of cavities is firmly related to occurrence of microleakage, especially if filled with composite and dental adhesive (16).

One of the weakest links of Class II composite restorations is leakage at the gingival margin of proximal boxes. This is due to the absence of enamel at gingival margins implying a less stable and uniform cementum-dentin substrate for bonding. This is supported by Fabianelli (2004) who reported the presence of an outer layer, partially formed by cementum, of 150-200 microns located below the CEJ which does not allow micro-retentions for adhesive materials (16). The orientation of dentinal tubules can negatively affect the quality of hybridization, thus favoring leakage in resin-based restorations placed in deep inter-proximal boxes (16).

The results of this investigation showed that bonded ceramic inlay restorations could significantly produce less leakage than direct resin composite restorations, especially at non-enamel level.

This can be correlated to two main points:

1 The main advantage of ceramic inlays over resin composite restorations in large class II cavities, which is the limited volume of contracting luting resin composite formulations used.

2 The coefficient of thermal expansion and contraction of the ceramic material is close to that of tooth structure while resin composite expands and contracts significantly greater than the tooth upon heating and cooling.

It is, therefore, expected that bonded ceramic restorations would better seal the gingival margins, especially at non- enamel sites where establishing and maintaining strong resisting bonds is less likely. In a similar pattern, Neila et al. (2005) (17) found that the indirect resin Solidex and the ceramic system Vitadur provided a better sealing at cervical margins of Class II MOD posterior inlays than the Charisma resin composite placed directly and indirectly. In their investigation, the gingival margins were placed 1 mm below the cemento-enamel junction.

Furthermore, Uludag et al. (2009) (18) studied the microleakage of ceramic inlays luted with different resin cements and dentin adhesives using the dye penetration method at enamel and dentin margins. They found that the overall microleakage at the enamel margins was significantly less than at the non-enamel margins.

In sound posterior teeth, buccal and lingual cusps are interconnected by the occlusal enamel and the marginal ridges. Once these stabilizing/cross linking elements are sacritek im je tada ispitana frakturna otpornost. Restaurirani zubi ponašaju se drugačije od zdravih i intaktnih podvrgnutih istim okluzalnim uvjetima opterećenja - oni raspoređuju stres homogenije jer se caklina ne deformira, nego se deformacija prenosi na otporniji dentin. Kad se kontinuitet cakline izgubi zbog pukotine ili preparacije kaviteta, svojstva dentina glavna su u ponašanju kvržica pod opterećenjem (2, 3, 19-21). Najčešće korištena metoda za procjenu snage prepariranog i/ili restauriranog zuba jest primjena statičkog opterećenja do trenutka pucanja. Na rezultate takvih istraživanja utječu kvaliteta te veličina i morfološke značajke testiranih zuba, pa su podložni velikim varijacijama (2).

U našem istraživanju frakturna otpornost nerestauriranih prepariranih zuba (C1 i C2) bila je znatno niža od intaktnih zuba (C). Smanjivanje frakturne otpornosti bilo je nešto veće u skupini C2 gdje su gingivni rubovi preparacije bili apikalnije nego u skupini C1 kod koje je gingivni rub bio okluzalnije, ali statistička razlika nije bila velika. Slične rezultate dobili su i Vale (22) te Mondelli i njegovi suradnici. (23). Reel i Mitchel (24) izvijestili su da su nerestaurirane MOD-preparacije duboke tri milimetra okluzalno i široke polovinu dužine, među kvržicama bukolingvalno imale samo 25 posto frakturne otpornosti zabilježene kod intaktnih zuba. Jagadish (25) je ustanovio da otpornost nerestauriranih zuba iznosi 43 posto one zabilježene kod intaktnih. Prema rezultatima tih istraživanja, zubi s MOD-preparacijama znatno su oslabljeni zbog gubitka potporne i prstenaste stabilizirajuće strukture, poput marginalnih i poprečnih grebena. Hood (26) je proučavao biomehaniku intaktnih, prepariranih i restauriranih zuba i zaključio da se stupanj ogiba kvržica povećava s dubinom preparacije. Rezultati ovog istraživanja pokazali su da postavljene adhezivne restauracije mogu djelomice kompenzirati učinak oslabljivanja preparacije kaviteta na testiranim uzorcima, bez statistički značajne razlike između dviju korištenih metoda restauracije. Kod skupine s gingivnim rubovima preparacije smještenima apikalnije, restaurativne tehnike statistički su bile neznatno manje učinkovite u pojačavanju preostale zubne strukture, što se slaže s rezultatima istraživanja Reela i Mitchella (24), Watta (27) i ostalih (28, 29) koji su ustanovili da se frakturna otpornost djelomice vraća korištenjem adhezivnih smola i keramičkih inlaya u usporedbi s intaktnim zubima. Meerbeek i suradnici (8) tvrde da adhezivne restauracije bolje prenose i raspoređuju funkcionalni stres preko adhezivnog spoja na zub i mogu pojačati oslabljenu strukturu zuba bolje nego konvencionalne neadhezivne restauracije. Adhezivna veza između restaurativnih materijala i zuba ima biomehaničku ulogu u raspodjeli funkcijskog stresa na cijeli zub (30 - 33).

Prava i učinkovita veza zub - restauracija imala bi glavnu ulogu u osiguravanju povoljnog oblika prijenosa stresa (8, 30 -35).

Suprotno ovim istraživanjima, Jensen i suradnici (11), koristeći se adhezivnim kompozitnim materijalima, nisu našli statistički značajnu razliku između frakturne otpornosti intaktnih i restauriranih zuba. Takve varijacije mogle bi biti rezultat razlika u konfiguraciji kaviteta i primijenjenih metoda testiranja.

ficed during cavity preparation, the cusps are more easily deformed and forced apart during occlusal loading and become more susceptible to fracture (1, 2).

Previous studies have tested the cusp fracture resistance of adhesively restored teeth (5, 6). In this study, the long term behavior of two different adhesive restorations, resin composite and ceramic inlays was in the focus of our interest. Restored specimens were therefore only tested after exposure to thermal and occlusal load cycling challenges. Restored teeth respond differently than intact and healthy teeth under the same occlusal loading conditions. Healthy teeth distribute stresses more homogeneously, because enamel is not appreciably deformed and the deformation is transferred to the more resilient dentin. When the continuity of the enamel is lost due to crack or cavity preparation, the properties of dentin play a major role in cusp behavior (2, 3, 19-21).

The most frequently used method for the evaluation of the strength of prepared and/or restored teeth is the application of static load until failure occurs. The results of this type of experiment are influenced by the quality, size, and morphological aspects of the test teeth and therefore, subject to considerable variation (2).

In the present study, the strength of un-restored teeth (groups C1 and C2) was significantly lower than the intact teeth (C). The deterioration in fracture resistance was statistically insignificantly higher for group C2 where the gingival margins were more apically placed than in group C1 where the gingival margins were more occlusally located. This is similar to the previous findings of Vale (22) and Mondelli et al. (23). Reel and Mitchell (24) reported that unrestored MOD preparations 3mm deep occlusally and one half intercuspal distance buccolingually wide were only 25% as strong as intact teeth. Jagadish (25), on the other hand, found that the resistance of unrestored teeth was 43% of that of the intact teeth. According to these studies, the teeth with MOD preparations are severely weakened due to the loss of reinforcing and cross belting structures, such as marginal ridges and crossing ridges.

Hood (26) studied the biomechanics of the intact, prepared and restored teeth. He concluded that the degree of cuspal deflection increases with the depth of the preparation. The results of this investigation showed that the adhesive restorations used have partly compensated for the weakening effects of cavity preparation with insignificant difference in effect between the differently restored groups of specimens. Furthermore, the restorations were insignificantly less effective in compensating for the weakening effects of the preparation when the gingival margins were extended more apically. This is in accordance with the results found by Reel and Mitchell (24), Watts (27) and others (28, 29) who found that the fracture strength was partly regained through the use of adhesive resin composite and ceramic inlays when compared to intact teeth.

According to Meerbeek et al. (8), adhesive restorations better transmit and distribute functional stresses across the bonding interface to the tooth and have the potential to reinforce weakened tooth structure than the conventional nonbonded restorations. The adhesive bond between a restorative

Prijašnja *in vitro* mehanička testiranja adhezivnih restauracija II. razreda upućivala su na različite utjecaje restaurativnog materijala, adhezivnog sustava i kompozitnog cementa u razdiobi stresa. Van Merbeek i suradnici (8) smatraju da je iznimno važna krhkost ili elastični modul materijala korištenog za restauraciju i spojnog adhezivnog sloja. Stupanj savijanja kvržica može djelomice kompenzirati kontrakcijski stres kod II. razreda adhezivno vezanih kompozitnih ispuna, ali polimerizacijska kontrakcija, koja je jedna od loših strana direktnih kompozitnih materijala, može uzrokovati napuknuća i potpune frakture kvržica (28 -30). Danas su keramički inlayi postali alternativa u područjima pod velikim pritiskom, posebice nakon nedavnih poboljšanja mehaničkih i fizikalnih svojstava keramičkih materijala, kompozitnih cementa i razvoja snažnih adhezivnih sustava (28, 29).

U literaturi se navodi da inlayi nude nadmoćnu estetiku, biokompatibilnost, stabilnost boje, otpornost na trošenje i niži stupanj akumulacije zubnog plaka nego caklina, te im je koeficijent termičke kontrakcije i ekspanzije blizu zubne cakline. Nadalje, minimiziraju problem polimerizacijske kontrakcije koja može ugroziti stvaranje i održavanje učinkovite veze zub - restauracija koja se pojavljuje kod izrade direktnih kompozitnih restauracija (2, 5, 28). Ausillo i suradnici (2) istaknuli su da kompozitni inlayi omogućuju bolje rasipanje i razdiobu stresa nego oni staklokeramički kod MOD-preparacija na modelu gornjih pretkutnjaka. Zaključili su da MOD-kaviteti restaurirani sa staklokeramičkim inlayima stvaraju veću razinu stresa na kvržicama negoli kompozitni koji imaju elastičnu biomehaniku sličniju zdravom zubu.

Suprotno njima, Ragauska i suradnici istaknuli su da adhezivno vezani MOD-keramički inlayi imaju sličnu frakturnu otpornost kao i intaktni nerestaurirani maksilarni pretkutnjak, dok su adhezivno postavljeni kompozitni ispuni pokazali 77 posto frakturne otpornosti intaktnih pretkutnjaka. U njihovu istraživanju okomiti se statički pritisak prenosio na zub i ispun, što je drugačije negoli u našem istraživanju u kojem su bile opterećene samo bukalna i lingvalna kvržica. L.V. Habekost i suradnici (38) usporedili su frakturnu otpornost pretkutnjaka podvrgnutih različitim postupcima, uključujući skupinu endodontski i neendodontski tretiranih zuba s MOD-kompozitnim ispunima u usporedbi s keramičkim inlayima. Dobili su slične rezultate kao Raguska i suradnici (37) u skupini MOD-restauriranih zuba s keramičkim inlayima, bez termičkog cikliranja i cikličkog opterećenja (38).

Varijacije u rezultatima istraživanja mogu se objasniti različitim tehnikama testiranja, s posebnim naglaskom na termičko cikliranje i cikličko opterećenje. Čini se da testiranje adhezivnih restauracija nakon umjetnog starenja daje realnije rezultate. Zato smatramo da bi umjetno starenje trebalo biti osnova za testiranje adhezivnih restauracija.

material and tooth has a biomechanical role in the distribution of functional stresses throughout the whole tooth (30-33).

A true efficient tooth-restoration bonding joint would play a major role in providing a favorable stress transfer pattern (8, 30-35).

On the other hand, Jensen et al. (11), found no significant difference in fracture resistance between intact teeth and the teeth restored with adhesive resin composite. Such variations in results could be due to differences in cavities configurations and testing methods.

Previous *in vitro* mechanical tests on Class II adhesive restorations revealed different aspects related to stress distribution pattern, clarifying the role of restorative material, of the adhesive resin and of the resin cement.

According to Van Merbeek et al. (8), the rigidity or elastic modulus of the restorative material, and the adhesive adjoining interface is considered extremely important. A degree of bending of the cusps may compensate for the concentration of stresses in class II bonded resin composite restorations. However, polymerization contraction which is a main drawback of direct resin composite materials can induce cracking and cusp fracture (28-30).

Today, all- ceramic inlays became one of the available restorative options for stress bearing locations, especially with the recent improvements in the mechanical and physical properties of the ceramic materials, the resin luting cements, and the development of high-strength bonding systems (28, 29).

It has been reported that ceramic inlays provide superior esthetics, biocompatibility, color stability, wear resistance, and lower plaque retention behavior than enamel with coefficient of thermal expansion and contraction close to that of human enamel. Furthermore, they minimize the problem of polymerization contraction stresses that can jeopardize the development and maintenance of an efficient tooth-restoration interfacial bond when composite resin restorations are made directly (2, 5, 28).

Ausillo et al. (2) found that composite resin inlays provide better stress dissipation and re-distribution than glass ceramic inlays in MOD inlays in upper premolars models. They concluded that MOD cavities restored with glass ceramic inlays created higher stress levels at the cusps and that resin composite inlays presented elastic biomechanics similar to that of the sound tooth.

On the other hand, Ragauska et al. (37) found that bonded MOD ceramic inlays produced similar tooth fracture resistance to intact unrestored maxillary premolars while resin composite restorations produced only 77% of the fracture resistance of intact premolar teeth. In their study, the vertical static loading pattern included both the tooth and the restoration, contrary to our study where only the buccal and lingual cusps were loaded.

Habekost L. V. et al. (38), compared fracture resistance of premolar teeth with different treatments including endodontically treated group and non-endodontically treated group with MOD composite resin versus ceramic inlay restorations. They reported similar results to those of Raguska et al. (37) in the group restored with MOD ceramic inlays restorations without thermocycling or load cycling (38).

Such differences in findings could be explained by differences in testing techniques with special respect to thermal and occlusal load cycling. Apparently, testing the effectiveness of adhesive restorations after artificial aging provides a more realistic outcome. Therefore, we support the fact that artificial aging should be a basic adjunct in testing adhesive restorations.

Zaključci

U skladu s rezultatima ovog istraživanja i uzevši u obzir ograničenja primijenjenih testova može se zaključiti sljedeće:

1. mikropropusnost na cervikalnoj stijenki MOD-kaviteta još je izazov, unatoč primjeni suvremenih adhezivnih sredstava, posebice ako je stijenka bez cakline;
2. adhezivni kompozitni ispuni pokazali su znatno raspadanje veze prianjanja kod gingivnih stijenki bez cakline, u odnosu na one s caklinom, no kod adhezivno cementiranih keramičkih inlaya takav učinak nije bio značajan;
3. adhezivno cementirani keramički inlayi pouzdanije brtve cervikalne rubove MOD-restauracija nego kompozitni, posebice ako su stijenke bez cakline;
4. preparacije MOD-kaviteta znatno su smanjile frakturnu otpornost kvržica maksilarnih pretkutnjaka; nešto veće opadanje frakturne otpornosti bilo je kod apikalnije smještenih cervikalnih rubova, ali razlika nije velika;
5. direktni kompozitni ispuni i keramički inlayi djelomice su kompenzirali učinak oslabljivanja zbog preparacije kaviteta; ako su restauracije bile postavljene apikalnije bile su nešto manje učinkovite u tom pojačanju, ali razlika nije bila znatna;
6. različiti materijali podjednako su, bez veće razlike, kompenzirali učinak oslabljivanja zbog preparacije kaviteta.

Conclusions

According to the results of this investigation and taking into consideration the limitations of the implemented tests as well as the encountered uncontrollable variables, the following conclusions could be drawn:

1. Microleakage at the cervical margins of MOD restorations is still a challenge even with the contemporary adhesive systems, especially at non-enamel margins.
2. While bonded composite resin restorations showed a significant deterioration in adaptation at non-enamel relative to enamel-located cervical margins, such effect was only insignificant for bonded ceramic inlay restorations.
3. Bonded ceramic inlays are more reliable in sealing the cervical margins of MOD restorations than resin composite restorations, especially at non-enamel margins.
4. MOD cavity preparation produced a significant deterioration in maxillary premolars cusp fracture resistance. A further insignificant deterioration occurred when the cervical margins were more apically placed.
5. Composite resin direct restorations and ceramic inlays partly compensated for the weakening effects of cavity preparation. The restorations were insignificantly less effective in this respect when the cervical margins were placed more apically.
6. Compensation of the weakening effects of cavity preparation was not significantly influenced by the type of restoration used.

Abstract

Purpose: This *in vitro* investigation was performed to assess microleakage and cusp fracture resistance of maxillary premolars specimens involving composite resin direct restorations and ceramic inlay restorations. **Material and methods:** Specimens were tested after artificial aging provoked by thermal and occlusal load cycling. For that purpose, 66 extracted maxillary premolars were used with six premolars in each study group. Standardized MOD cavities were prepared and classified into two main groups according to gingival-margins location either 1mm above (A1) or 1 mm below (A2) the CEJ. Specimens were subdivided into two subgroups: Z250 composite resin direct restorations and IPS Empress glass ceramic restorations cemented with Variolink II resin-cement. Group of intact teeth specimens and two groups of A1 and A2 type prepared but not restored teeth served as control groups. Restored teeth were mounted in acrylic-resin blocks before loading and thermocycling. Microleakage was assessed by examining dye penetration scores under Zeiss-stereomicroscope. Cusp fracture resistance was performed using vertical static loading until failure. The fracture-load test mean values and microleakage results were statistically analyzed. **Results:** Investigated restorations showed insignificant difference in adaptation at enamel margins. Ceramic restorations showed better sealability and tooth structure reinforcing effects than composite restorations, especially at non-enamel margins. **Conclusions:** Cavity preparation produced significant weakening effect. Restorations just partly compensated weakening effect of cavity preparation. Upgrading the performance of adhesive restorations in terms of adaptation and tooth structure reinforcement poses a continuing challenge to restorative dentistry.

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Bicuspid; Dental Bonding; Dental Cavity Preparation; Composite Resins; Metal Ceramic Alloys; Tooth Fractures; Dental Leakage

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