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Scanning Electron Microscopy Analysis of Adhesive Bond of Glass-ionomer Cement Restorations

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SUMMARY

Introduction Lack of proper adhesion is one of the most common problems in modern restorative dentistry and the main cause of the occurrence of microcracks at the interface between materials and hard dental tissue. The aim of this study was to assess the quality of bond between two types of glass-ionomer cement (GIC) class V restorations and hard dental tissues by SEM.

Materials and Methods This clinical study included 20 intact teeth (premolars and molars) recently extracted for orthodontic reasons in patients of both genders and different ages. Class V cavity with rounded walls was prepared on vestibular and oral surfaces of all teeth (3x2x2 mm). Conventional GIC Fuji II was applied on vestibular surface of teeth whereas on oral surface resin-reinforced glass ionomer Fuji II LC was placed. The bond between fillings and hard dental tissue was assessed by SEM.

Results Both materials showed microcracks, however, microleakage was lower with Fuji II LC than with Fuji II. Microcracks were observed in 65% of cases (13 restorations) restored with GIC Fuji II and 35% (7 fillings) restored with GIC Fuji II LC. The size of microcracks for Fuji II LC was 9 μm while this value for Fuji II was 17 μm. The difference was statistically significant.

Conclusion Better bond between material and hard dental tissue was achieved with the material of new generation, resin modified GIC.

Keywords: adhesiveness; glass-ionomer cement; microfracture; scanning electron microscopic (SEM) analysis

INTRODUCTION

The greatest problem in restorative dentistry is adhesiveness or establishing adequate bond between material and hard tooth substance. Lack of proper adhesion is considered the main cause of microcracks and consequent microleakage. Microleakage is dynamic phenomenon and considers undetected penetration of liquids, bacteria, molecules or ions between cavities and fillings clinically manifested as marginal discoloration, damage of the edges of fillings, and signs of pulp irritation or inflammation or the presence of secondary caries [1, 2]. Glass-ionomer cements (GIC) are widely used in restorative dentistry today. The emergence of this material was of great importance in dentistry because it was the first material that had good adhesion and chemical bond with enamel and dentin [3, 4].

From the first use of GIC in 1972 they went through number of changes and improvements. The most important change has been the addition of resin to conventional GIC. This way some of the biggest drawbacks of conventional GIC such as sensitivity to water imbalance have been overcome while mechanical and aesthetic properties have been improved [5, 6]. The most important features of these materials are good adhesion, dimensional stability and almost identical coefficient of thermal expansion with hard dental tissues as well as biocompatibility and release of fluoride [7-11].

These materials achieve chemical bond with hydroxyapatite of enamel and dentin. Bond strength between GIC and enamel ranges from 2.6 to 9.6 MPa (with most other materials it ranges 4-6 MPa) while with dentin it is twice smaller 1.1 to 4.5 MPa. Adhesion between GIC and enamel is stronger than with dentin, it means that this material rarely breaks on the bond with tooth structure, it is usually cohesion defect in the material, and rarely in dentin [2].

Dimensional changes of these materials are the consequence of chemical reactions responsible for setting (polymerization) and response to thermal changes in oral cavity (thermal contraction or expansion) [2]. Polymerization contraction in conventional GIC is minimal (less than 0.2%), while in hybrid GIC it is slightly higher (about 0.2%), however, it is still far lower than that for composites [3]. The coefficient of thermal expansion and contraction of GIC is very close to values for enamel and dentin.

The aim of this study was to assess the quality of bond between two types of glass-ionomer cement (GIC) class V restorations and hard dental tissues by SEM.

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MATERIALS AND METHODS

Twenty human teeth (premolars and molars) freshly extracted for orthodontic reasons were used in this study. Class V cavity with rounded walls was prepared on vestibular and oral surfaces of all teeth (3×2×2 mm). Cavity edges were placed in enamel and enamel prisms were not beveled. Cavities in enamel were prepared using highspeed handpiece with diamond bur and water cooling. For the preparation in dentin slowspeed handpiece with steel round burs was used. After cavity preparation walls were conditioned (Cavity Conditioner), washed with water and dried with sterile cotton balls. The material was placed in cavities in accordance with the manufacturer's instructions. Conventional GIC Fuji II (GC Japan) was placed in vestibular cavity while resin modified GIC Fuji II LC (GC Japan) was applied in oral cavity. Materials were polymerized using halogen lamp (Bluephase C8, Ivoclar Vivadent). They were coated with GIC Fuji Varnish, air dried and polished. The teeth were then subjected to different temperature protocols at +4° C, +37° C and +56° C.

Teeth were kept in saline before SEM analysis was performed. After splitting teeth in vestibulo-oral direction, sections were fixed on metal rollers and coated with thin layer of precious metal in a vacuum apparatus. Samples were observed using scanning electron microscope (SEM) JEOL JSM-5300 at maximum voltage of 30 kV using different magnifications. SEM images were obtained using JVC GC-X3E on films ILFORD FP4 PLUS 125 (125 ASA, 22DIN, EI 125/22). Bond between hard dental tissue and GIC materials as well as possible occurrence of microleakage was analyzed. Image analysis and measurement of the size of microcracks were performed in the computer software SemAfore 4.

RESULTS

In teeth restored with GIC Fuji II microcracks were observed in 65% of cases (13 restorations) whereas they were found in 35% of cases (7 restorations) when GIC Fuji II LC was used (Table 1).

Table 1. Size of microcracks in GIC restorations
Tabela 1. Vrednosti mikropukotine kod GJC restauracija

No.	Fuji II (μm)	Fuji II LC (μm)
1.	0	11.5
2.	20.5	0
3.	16	0
4.	19.5	12.5
5.	16	0
6.	15	0
7.	18	7.5
8.	13.5	0
9.	0	6.5
10.	15.5	0
11.	0	8.5
12.	18.5	0
13.	17	7
14.	15	0
15.	0	0
16.	19	0
17.	0	0
18.	17.5	0
19.	0	9.5
20.	0	0

SEM analysis of relationship between Fuji II and hard dental tissues showed interesting results. In some teeth clear microcracks were observed on microphotographs, whereas in some cases high-quality adhesion and close contact of material and hard dental tissues was detected. Figure 1 shows the bottom of the cavity filled with Fuji II GIC. There is visible microcrack (MC) between dentin (D) and filling (GIC) with the size of 13 to 14.7 μm. Close contact and continuous bond between Fuji II and hard dental tissues, better with enamel than dentin, can be seen in Figure 2. Connection area between Fuji II (GIC) and dentin (D) shows microspace as a result of inadequate bond between glass-ionomer materials and hard dental tissues. This type of fracture is adhesive fracture as confirmed by the crack that is a result of glass-ionomer separation from dental tissues, evidenced by GIC impression on the corresponding wall of the cavity (Figure 3). The absence of continuous bond between Fuji II (GIC) and enamel (E) can be seen in Figure 4. However, much stronger bond between GIC and enamel, as compared to GIC and dentin is shown in Figure 5a (GIC and enamel bond) and Figure 5b (GIC and dentin bond). Continuous bond is obvious in Figure 5a and microcracks in Figure 5b.

SEM micrographs of bond between Fuji II LC and hard dental tissues showed microcracks in majority of cases between the material and dentin, and rarely between enamel and GIC. Good adhesion of Fuji II LC (GIC) for dentin (D) is observed in Figures 6a and 6b where the bottom of

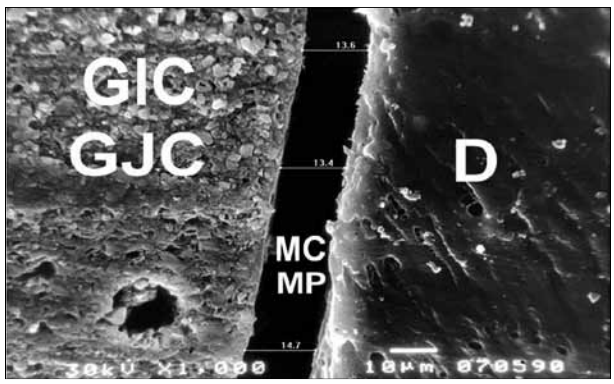

Figure 1. Bottom of the cavity filled with Fuji II GIC. There is visible microcrack (MC) between dentin (D) and the filling (GIC) (13-14.7 μm).
Slika 1. Dno kaviteta pokriveno materijalom Fuji II. Uočava se mikropukotina (MP) između dentina (D) i ispuna (GJC) sa veličinom mikropukotine u rasponu 13–14,7 μm.

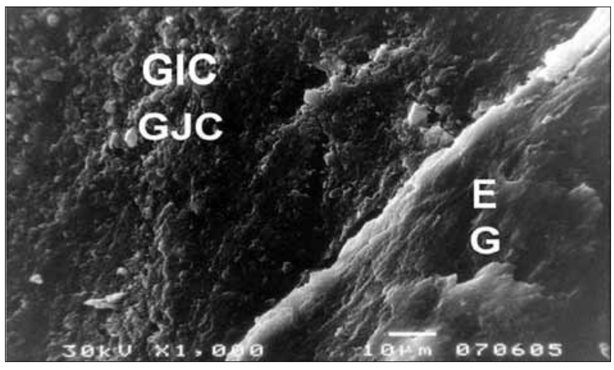

Figure 2. Close contact and continuous bond between Fuji II and hard dental tissues (better contact with enamel)
Slika 2. Intiman i kontinuiran spoj između Fuji II i gleđi (G) i dentina (D) (bolji kontakt sa gleđi)

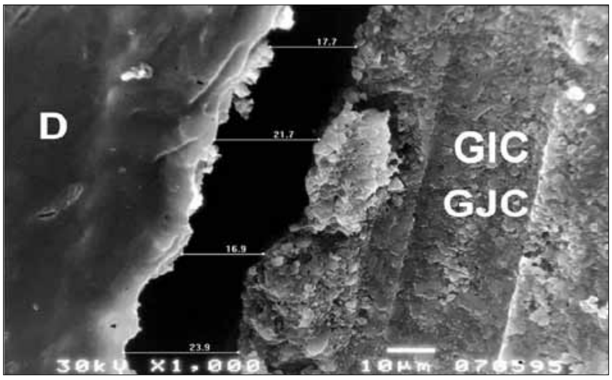

Figure 3. Adhesive fracture of Fuji II. A micro crack is visible between GIC material and hard dental tissues.
Slika 3. Adhezivni prelom materijala Fuji II. GJC materijal odvojen pukotinom od tvrdih zubnih tkiva.

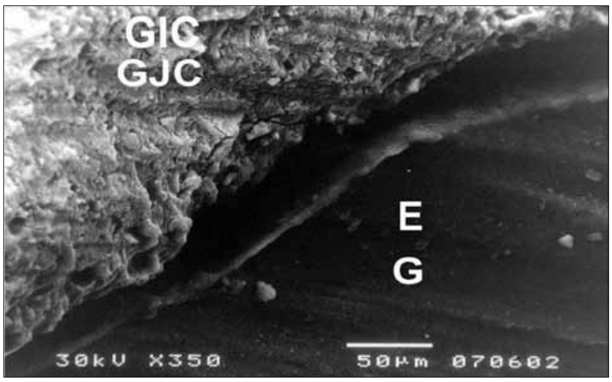

Figure 4. The absence of continuous bond between Fuji II (GIC) and enamel (E)
Slika 4. Izostanak kontinuiranog spoja između materijala Fuji II (GJC) i gleđi (G)

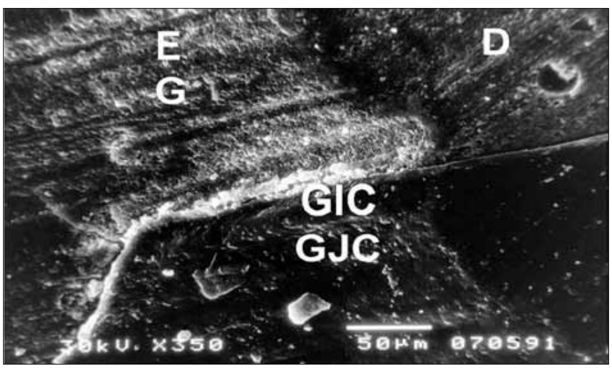

Figure 5a. Continuous bond between Fuji II (GIC) and enamel (E)
Slika 5a. Kontinuirani spoj između Fuji II (GJC) i gleđi (G)

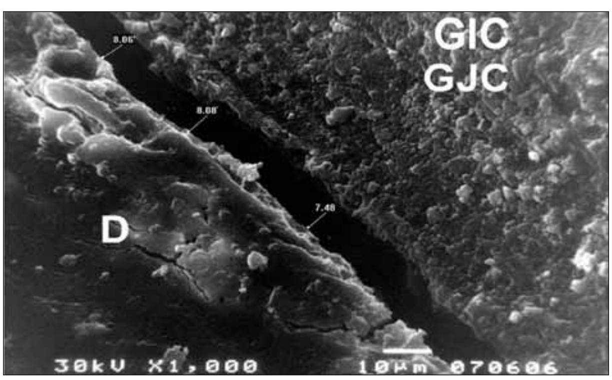

Figure 5b. A microcrack between Fuji II (GIC) and dentin (D)
Slika 5b. Mikropukotina između Fuji II (GJC) i dentina (D)

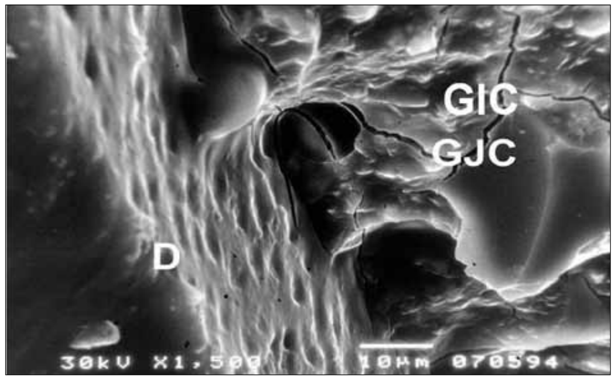

Figure 6a. Good adhesive bond between Fuji II LC (GIC) and dentin (D) at the bottom of the cavity (×1,500 magnification)
Slika 6a. Dobra adhezivna veza između Fuji II LC (GIC) i dentina (D) na dnu kaviteta (uvećanje 1.500 puta)

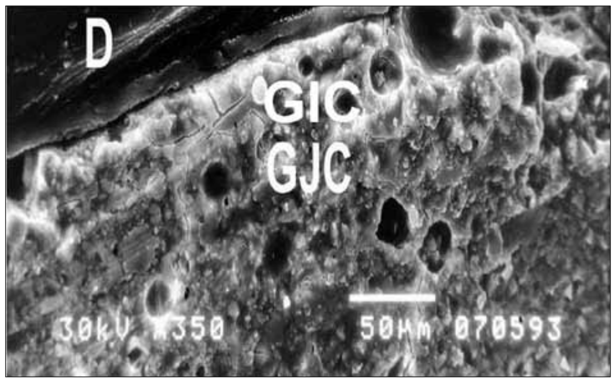

Figure 6b. Good adhesive bond between Fuji II LC (GIC) and dentin (D) on the wall of the cavity (×350 magnification)
Slika 6b. Dobra adhezivna veza između Fuji II LC (GIC) i dentina (D) na zidu kaviteta (uvećanje 350 puta)

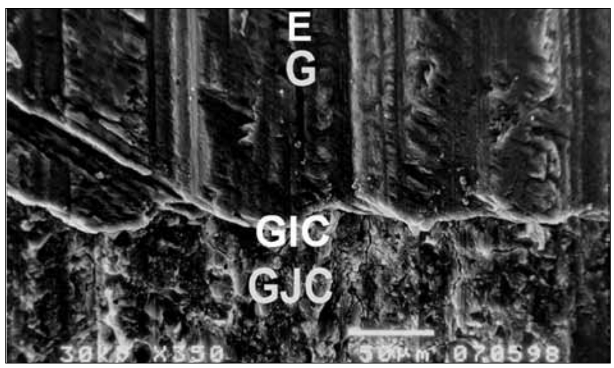

Figure 7. Continuous adhesive bond between Fuji II LC (GIC) and enamel (E) (×350 magnification)
Slika 7. Kontinuirani adhezivni spoj između Fuji II LC (GJC) i gleđi (G) (uvećanje 350 puta)

the cavity is shown with magnification x1500, and walls with magnification x350. Continuous and good adhesive bond between Fuji II LC (GIC) and enamel (E) is shown on Figure 7. The absence of microcrack was noticed in the contact area between Fuji II LC (GIC) and dentin (D) at the bottom of cavity (Figure 8). On microphotographs that show bond between Fuji II LC (GIC) and hard dental tissues, close contact between GIC and enamel (E) can be seen (Figure 9a), but the presence of microcracks in the area of GIC contact with dentin (D) in the bottom of cavity (Figure 9b). The microphotograph 9b shows exposed open dentinal tubules.

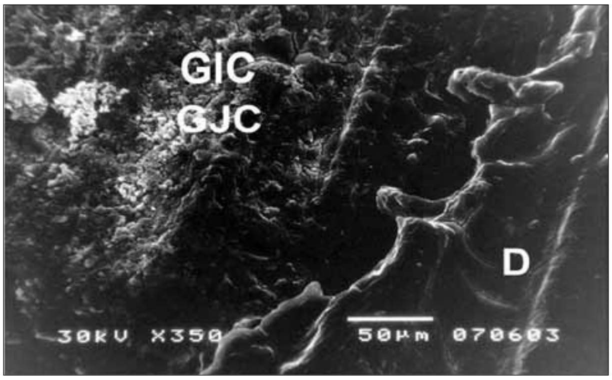

Figure 8. The absence of microcrack in the contact area between Fuji II LC (GIC) and dentin (D) at the bottom of the cavity (×350 magnification)
Slika 8. Odsustvo mikropukotine u predelu kontakta između Fuji II LC (GJC) i dentina (D) na dnu kaviteta (uvećanje 350 puta)

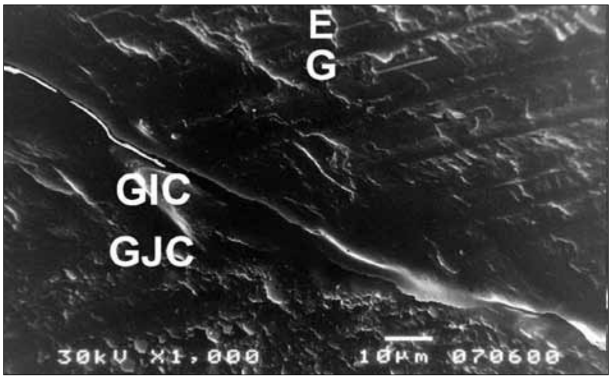

Figure 9a. Close contact between Fuji II LC (GIC) and enamel (E) (×1,000 magnification)
Slika 9a. Intiman kontakt između Fuji II LC (GJC) i gleđi (G) (uvećanje 1.000 puta)

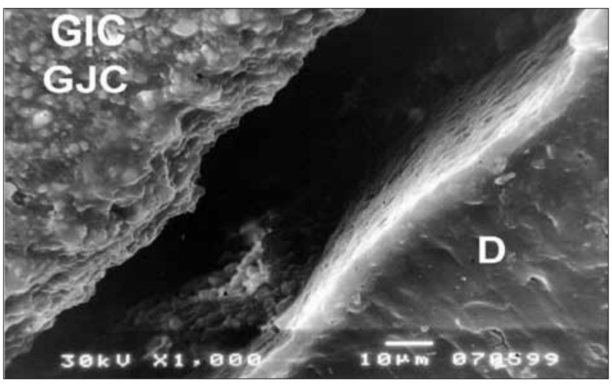

Figure 9b. The presence of microcrack in the area of contact between Fuji II LC (GIC) and dentin (D) at the bottom of the cavity (×1,000 magnification)
Slika 9b. Mikropukotina na mestu kontakta Fuji II LC (GIC) i dentina (D) na dnu kaviteta (uvećanje 1.000 puta)

SEM analysis revealed the size of microcracks for Fuji II LC was about 9 µm (7 teeth), while this value was 17 µm for Fuji II (13 teeth). Regardless of exposure to various temperature changes the total number of teeth with microcracks was lower in Fuji II LC group (7 restorations) than Fuji II (13 restorations). This difference was statistically significant. It was also found that bond between two examined GIC materials and enamel was much better than between the two GIC and dentin.

DISCUSSION

GIC are widely used in modern dentistry due to their favorable properties. GC Fuji II is representative of the group of conventional GIC. Conditioning of hard tissues with mild solution of polyacrylic acid in order to remove smear layer and preactivate Ca^{2+} ions is required for this material application. After placement, this material is extremely sensitive to moisture; therefore, it is needed to apply protective coating for necessary insulation.

GC Fuji II LC is representative of resin-modified glass ionomer cements. These materials are manufactured by adding composite resin to conventional GIC. The addition of resin solved one of the biggest drawbacks of conventional GIC- sensitivity to water imbalance. Differences in the size of microcracks of investigated materials and better adhesive bond achieved with GC Fuji II LC can be explained by different reaction of materials to water imbalance.

Somewhere between 11 and 24 % of cured cement is water, therefore GIC are considered water-based cements. Water content can be arbitrarily divided into "loosely bound" water, easily removed by dehydration and "tightly bound" water that cannot be removed and remains an important part of curing reaction and final cured cement. The presence of water is essential for cement setting. Without water as a medium there is no acid-base reaction. Water also affects stabilization of Al-polycarboxylate complex forming coordinate connections with it [2].

Regardless of the type of GIC, these materials are vulnerable during the period of polymerization, immediately after placing material in the cavity. Resin-modified glass ionomer (resGIC) such as Fuji II LC has a tremendous advantage in this phase. In conventional GIC, Ca-polyacrylate chains are formed first and then Al-polyacrylate chains. When it comes to resGIC, there is exactly the same acid-base reaction which is here protected from water imbalance by resin polymerization [12, 13]. 80% of bond strength between GIC and hard dental tissues develops in the first fifteen minutes of material setting.

There are different opinions about factors that contribute to reinforcing links between GIC and tooth structure. However, most scientists believe that ionic and hydrogen bonds are responsible for bond strength between GIC and teeth [2, 6, 12, 13].

Although resGIC exhibit stronger adhesion to hard dental tissues than conventional GIC, they show different results of microleakage. However, most of them show lower microleakage than conventional GIC [6, 14].

As the coefficient of thermal expansion of these materials has a value similar to hard dental tissues it adds to good marginal seal [14, 15]. GIC does not show significant dimensional changes in the process of setting and hardening.

Better marginal seal of resGIC is obtained because of their lower solubility in water (for conventional GIC it is 0.07% whereas for resGIC it is 0.03%), different behavior in acidic environment (conventional GIC are soluble in acids 0.33 (mm/h) (%), while in resGIC slight swelling occurs), and the fact that resGIC are not sensitive to water imbalance [2, 11].

Results of the current study are consistent with results of the study done by Hallet and Garcia-Godoy [16]. They compared microleakage of two resGIC and two conventional GIC where SEM analysis showed marked reduction in microleakage with resGIC. Sidhu [17] examined adhesion of two light-curable GIC: Fuji II LC and VariGlas VLC to dentin. Teeth were randomly divided in three groups: control group teeth were restored with chemically-curable GIC, Fuji Cap II, while the teeth in other two groups were restored with Fuji II LC and VariGlas VLC. Mean value of the size of microcracks registered in control group was 26 μm, while in experimental groups this value was 8 μm (Fuji II LC) and 10 μm (VariGlas VLC). Gladys et al. [18] compared marginal sealing of two composite materials, one compomer, two conventional GIC and three resGIC materials. All tested materials showed microleakage, the lowest was in resGIC. Similar results were obtained by Sjödin et al. [19], who found lower microleakage in resGIC and compomers than conventional GIC. Gupta et al. [20] investigated microleakage in composite restorations that contained either conventional GIC or resGIC as a base. Better performance and lower microleakage was registered in teeth where resGIC was used as base. Castro et al. [21] compared microleakage of Fuji IX, Fuji II (conventional GIC), Vitremera (resGIC) and composites. Results of their study showed that Fuji II had higher microleakage than all other tested materials.

Data from literature suggest that microleakage has complex nature and it is present with all restorative materials, however, it is the lowest in resGIC. The main reason for this is the fact that GIC have the most coherent coefficient of thermal expansion and develop primarily chemical bond with hard dental tissues compared to other restorative materials [3, 22, 23]. However, fatigue tests showed that all restorative materials subjected to cyclic loading undergo drop resistance to breakage (develop cracks) [24]. This resistance of conventional and hybrid ionomers is similar to values for composites with microparticles. The values of resistance of compomers are similar to hybrid composites in the initial stage, whereas after longer exposure to forces the properties of glass-ionomer materials take over.

CONCLUSION

Based on present results it can be concluded that better adhesive bond with hard dental tissues was achieved using resin modified GIC Fuji II LC. SEM analysis showed lower values for microcracks in GIC Fuji II LC compared to conventional GIC Fuji II.

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SEM analiza kvaliteta adhezivne veze glasjonomercementnih restauracija

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KRATAK SADRŽAJ

Uvod Nedostatak odgovarajuće adhezivnosti je jedan od najčešćih problema u savremenoj restaurativnoj stomatologiji i glavni uzrok nastanka mikropukotine na spoju materijala i tvrdih zubnih tkiva. Cilj ovog rada je bio da se SEM (skening-elektronska mikroskopija) analizom proveri kvalitet veze dve vrste glasjonomercementnih (GJC) restauracija za tvrda zubna tkiva kod kaviteta V klase.

Materijal i metode rada Kliničko istraživanje je obuhvatilo 20 sveže ekstrahovanih intaktnih zuba (premolari i molari), odstranjenih iz ortodontskih razloga kod pacijenata oba pola i različite starosti. Na svim zubima su sa vestibularne i oralne strane urađene jednopovršinske preparacije V klase adhezivnog tipa sa zaobljenim zidovima kaviteta (dimenzija 3×2×2 mm). Sa vestibularne strane primenjen je klasični GJC Fuji II, a sa oralne smolom ojačani GJC Fuji II LC. Kvalitet veze između ispuna i zubnih tkiva je procenjivan SEM analizom.

Rezultati Dobijeni nalazi su pokazali da je kod oba materijala zabeležena mikropukotina i da je stepen mikrocurenja kod Fuji II LC bio manji nego kod Fuji II. Kod zuba restaurisanih sa GJC Fuji II mikropukotina je uočena u 65% slučajeva (13 ispuna), a kod zuba restaurisanih sa GJC Fuji II LC u 35% slučajeva (sedam ispuna). SEM analizom je utvrđena srednja vrednost mikropukotine za Fuji II LC od 9 µm, dok je ova vrednost za Fuji II bila 17 µm. Razlika je bila statistički značajna.

Zaključak Na osnovu rezultata istraživanja može se zaključiti da je bolji kvalitet veze ostvaren primenom materijala novije generacije, odnosno primenom GJC modifikovanih smolom.

Ključne reči: adhezivnost; glasjonomer-cement; mikropukotina; skening-elektronska mikroskopija

UVOD

Najveći problem koji se pojavljuje u restaurativnoj stomatologiji je adhezivnost, odnosno uspostavljanje adekvatne veze između materijala i čvrste zubne supstance. Nedostatak odgovarajuće adhezivnosti smatra se glavnim uzrokom nastanka mikropukotine s posledičnom pojavom mikrocurenja. Mikrocurenje je dinamički fenomen i predstavlja neotkriveno prodiranje tečnosti, bakterija, molekula ili jona između kaviteta i ispuna, a klinički se manifestuje ivičnim prebojavanjem, oštećenjem rubova ispuna i nastankom znakova iritacije ili zapaljenjem pulpe zuba uz postojanje sekundarnog karijesa [1, 2]. Danas se nijedna intervencija u savremenoj restaurativnoj stomatologiji ne može zamisliti bez primene nekog oblika glasjonomer-cementa (GJC). Ovaj materijal je veoma značajan za stomatologiju, jer ostvaruje dobru adheziju i hemijsku vezu sa gleđnom i dentinskom površinom zuba [3, 4].

Od njegove pojave 1972. godine do danas, GJC su pretrpeli brojne promene i poboljšanja. Suštinska promena se ogleda u dodavanju kompozitnih smola u sastav konvencionalnih GJC. Time su rešeni najveći nedostaci konvencionalnih GJC, kao što su njihova osetljivost na disbalans vode, ali i poboljšanje mehaničkih i estetskih osobina [5, 6]. Osobine koje ove materijale odvajaju od drugih restaurativnih materijala su, pre svega, adhezivnost, dimenzionalna stabilnost i gotovo istovetan koeficijent termičke ekspanzije kao i kod tvrdih zubnih tkiva, ali i dobra biokompatibilnost i oslobađanje fluorida [7-11].

Ovi materijali se ubrajaju u adhezivne jer ostvaruju hemijsku vezu sa hidroksiapatitom gleđi i dentina. Jačina veze GJC sa gleđi je u rasponu 2,6–9,6 MPa (dok je kod većine drugih materijala u rasponu 4–6 MPa), dok je sa dentinom dvostruko manja (1,1–4,5 MPa). Dakle, adhezija za gleđ je jača nego za dentin, što znači da materijal retko puca na mestu same veze za zubna tkiva, već je najčešće reč o kohezionom defektu u samom materijalu, retko u dentinu [2].

Dimenzionalne promene materijala nastaju kao posledica hemijskih reakcija odgovornih za stvrdnjavanje materijala (polimerizacija) i reakcija na termičke promene u usnoj duplji (termička kontrakcija ili ekspanzija) [2]. Kod klasičnih GJC polimerizaciona kontrakcija je minimalna (do 0,2%), dok je kod hibridnih nešto veća (oko 0,2%), što je i dalje daleko ispod vrednosti zabeleženih za kompozite [3]. Vrednosti koeficijenta termičke kontrakcije i ekspanzije kod GJC je veoma slična vrednostima za gleđ i dentin.

Cilj rada je bio da se SEM analizom proveri kvalitet veze dve vrste GJC restauracija za tvrda zubna tkiva kod kaviteta V klase.

MATERIJAL I METODE RADA

Kao materijal u istraživanju korišćeno je 20 humanih sveže ekstrahovanih intaktnih zuba (premolari i molari), odstranjenih iz ortodontskih razloga, koji su do eksperimenta čuvani u fiziološkom rastvoru. Na svim zubima sa vestibularne i oralne strane urađene su jednopovršinske preparacije adhezivnog tipa klase V sa zaobljenim zidovima kaviteta (dimenzija 3×2×2 mm). Rubovi kaviteta su bili potpuno u gleđi, a gleđne prizme nisu zakošavane. Za preparaciju u gleđi korišćena je visokoturažna bušilica sa dijamantskim svrdlima i vodenim hlađenjem. Za preparaciju u dentinu je korišćen kolenjak sa čeličnim okruglim svrdlima. Nakon preparacije kaviteta urađeno je kondicioniranje površina, a potom su kaviteti isprani vodom i posušeni sterilnim kuglicama vate. U tako pripremljene kavitete postavljen je materijal u skladu s uputstvima proizvođača. Sa vestibularne strane primenjen je klasičan GJC Fuji II (*GC Japan*), a sa oralne strane GJC modifikovan smolom Fuji II LC (*GC Japan*). Posle unošenja materijala izvršena je polimerizacija halogenom lampom (*Bluephase C8, Ivoclar Vivadent*). Potom su ispuni premazani sa GJC Fuji Varnish i posušeni mlazom vazduha, a zatim ispolirani. Nakon ovoga zubi su podvrgnuti različitim temperaturnim protokolima i termociklirani na temperaturama od +4°C, +37°C i +56°C.

Zubi su do pripreme za SEM analizu držani u svežem fiziološkom rastvoru. Nakon cepanja zuba u vestibulo-oralnom pravcu, preseci su fiksirani na metalne valjke, a zatim u vakuum-aparatu naparavani tankim slojem plemenitih metala. Ovako dobijeni preparati posmatrani su skening-elektronskim mikroskopom JEOL JSM-5300 pri maksimalnom naponu od 30 kV i pri različitim uvećanjima.

Preparati su fotografisani aparatom JVC GC-X3E na filmovima ILFORD FP4 PLUS 125 (125 ASA, 22DIN, EI 125/22). Na snimcima je analiziran izgled veze, kao i eventualna pojava mikroprostora između zubnih tkiva i GJC ispuna. Za analizu fotografija, određivanje veličine mikropukotine i prikaz dobijenih vrednosti na fotografijama preparata korišćen je softver SemAfore 4.

REZULTATI

Kod zuba restaurisanih sa GJC Fuji II mikropukotina je zabeležena u 65% slučajeva (13 ispuna), a kod zuba restaurisanih sa GJC Fuji II LC u 35% slučajeva (sedam ispuna) (Tabela 1).

SEM analiza kvaliteta veze kod ispuna sa Fuji II pokazala je zanimljive rezultate. Na mikrofotografijama su uočeni i slučajevi s veoma izraženim mikropukotinama, ali i slučajevi sa kvalitetnom adhezijom i intimnim kontaktom materijala za zubna tkiva. Slika 1 prikazuje dno kaviteta ispunjenog materijalom Fuji II. Uočava se mikropukotina između dentina i ispuna s veličinom mikropukotine u rasponu 13–14,7 µm. Na slici 2 se uočava intiman i kontinuiran spoj između Fuji II i zubnih tkiva, s tim što se može zapaziti intimniji kontakt materijala sa gleđi nego sa dentinom. Pregledom spoja Fuji II i dentina vidi se mikroprostor nastao kao posledica neodgovarajuće veze glasjonomernog materijala. Da je reč o adhezivnom tipu oštećenja govori upravo izgled same pukotine koja je nastala odvajanjem glasjonomera od zubnog tkiva, o čemu svedoče impresije na glasjonomeru koje odgovaraju zidu preparacije (Slika 3). Izostanak kontinuiranog spoja između materijala Fuji II i gleđi može se videti na slici 4. Mnogo snažnija veza između GJC i gleđi, nego GJC i dentina, prikazana je na preparatima spoja Fuji II sa gleđi (Slika 5a), odnosno dentinom (Slika 5b). Jasno se uočavaju kontinuiran spoj na prvoj slici i mikropukotina na drugoj.

SEM analiza mikrofotografija, odnosno preparata kod kojih je korišćen Fuji II LC pokazala je da je pukotina u najvećem broju uzoraka bila vidljiva između materijala i dentina, a u malom broju između gleđi i materijala. Dobra adhezija materijala Fuji II LC za dentin zapaža se na slikama 6a i 6b, gde se vidi dno kaviteta pri uvećanju od 1.500 puta, odnosno bočni zid pri uvećanju od 350 puta. Kontinuirana i dobra adhezivna veza između Fuji II LC i gleđi prikazana je na slici 7. Izostanak pukotine je uočljiv i na preparatu koji prikazuje vezu Fuji II LC i dentina na dnu kaviteta (Slika 8). Na preparatima koji prikazuju odnos Fuji II LC sa zubnim tkivima uočava se intiman kontakt materijala i gleđi (Slika 9a), ali i mikropukotina u predelu spoja sa dentinom na dnu kaviteta (Slika 9b). Na slici 9a mogu se uočiti i eksponirani otvori dentinskih kanalića.

SEM analizom je utvrđena srednja vrednost mikropukotine za Fuji II LC od 9 µm (na sedam zuba), dok je ova vrednost za Fuji II bila 17 µm (na 13 zuba). Bez obzira na izlaganje različitim temperaturnim promenama, ukupan broj zuba sa mikropukotinom bio je manji kod Fuji II LC (sedam ispuna) nego kod Fuji II (13 ispuna). Ova razlika je bila statistički značajna. Takođe je uočeno da je veza oba ispitivana GJC sa gleđi bila mnogo bolja nego sa dentinom.

DISKUSIJA

Zahvaljujući svojim svojstvima, GJC su našli široku primenu u savremenoj stomatologiji. GC Fuji II je predstavnik grupe konvencionalnih GJC koja se danas najčešće koristi. Kod ovog materijala primenjuje se kondicioniranje tvrdih zubnih tkiva blagim rastvorom poliakrilne kiseline radi uklanjanja razmaznog sloja i preaktivacije jona Ca^{2+}. Nakon postavljanja ispuna materijal je izrazito osetljiv na vlagu, te je neophodna izolacija zaštitnim premazima. GC Fuji II LC je predstavnik smolom-modifikovanih GJC. Ovi materijali su dobijeni dodavanjem kompozitne smole u sastav konvencionalnih GJC. Ovo je urađeno da bi se rešio jedan od najvećih nedostataka konvencionalnih GJC – njihova osetljivost na disbalans vode. Razlike u veličini mikropukotine kod ispitivanih materijala i bolja adhezivna veza kod GC Fuji II LC mogu se objasniti različitom reakcijom samih materijala na disbalans vode.

Između 11% i 24% stvrdnutog cementa je voda, tako da se za GJC može reći da su na bazi vode. Udeo vode se proizvoljno deli na „slabo vezanu" vodu, koja se lako odstranjuje dehidratacijom, i „čvrsto vezanu" vodu, koja se ne može odstraniti i ostaje važan deo reakcije stvrdnjavanja i završno stvrdnutog cementa. Postojanje vode je od ključnog značaja za formiranje cementa. Bez nje kao medijuma nema ni acido-bazne reakcije. Ona utiče i na stabilizaciju Al-polikarboksilatnog kompleksa stvarajući s njim koordinatne veze [2].

Bez obzira na to o kojoj vrsti GJC je reč, materijal je najosetljiviji u periodu vezivanja, neposredno nakon unošenja materijala u kavitet. Upravo u ovoj fazi smolom-modifikovani GJC (smGJC), kao Fuji II LC, imaju ogromnu prednost. Kod klasičnog GJC prvo se formiraju Ca-poliakrilatni lanci, a zatim i Al-poliakrilatni lanci. Kada su u pitanju smGJC, javlja se potpuno ista acido-bazna reakcija, ali je ona zaštićena od disbalansa vode trenutnom polimerizacijom smole [12, 13]. Osamdeset posto jačine veze GJC sa zubnim tkivima se razvija u prvih petnaest minuta postavljanja materijala.

Vladaju različita mišljenja o faktorima koji doprinose pojačavanju veze između GJC i zubnog tkiva. Međutim, najveći broj istraživača smatra da su za čvrstoću veze odgovorne i jonske i vodonične veze [2, 6, 12, 13].

Iako smGJC ispoljavaju jaču snagu adhezije za tvrda zubna tkiva od konvencionalnih, oni pokazuju i različite rezultate u pojavi mikrocurenja. Ipak, većina njih pokazuje manji stepen mikrocurenja od konvencionalnih GJC [6, 14].

Kao značajan razlog dobrog rubnog zatvaranja GJC restauracija navodi se koeficijent termičke ekspanzije koji kod ovih materijala ima vrednosti veoma slične tvrdim zubnim tkivima [14, 15]. GJC ne trpi značajnije dimenzionalne promene pri procesu vezivanja i stvrdnjavanja cementa.

Kao razlozi boljeg rubnog zatvaranja smGJC navode se mnogo manja rastvorljivost u vodi (kod klasičnih ona je 0,07%, a kod smGJC 0,03%), različito ponašanje u kiseloj sredini (klasične GJC odlikuje rastvorljivost u kiselinama od 0,33 (mm/h) (%), dok se kod smGJC javlja blago bubrenje), te činjenica da smGJC nisu osetljivi na disbalans vode [2, 11].

Rezultati ovog istraživanja su u skladu s nalazima koje su dobili Halet (*Hallet*) i Garsija-Godoj (*Garcia-Godoy*) [16]. Oni su poredili stepen mikrocurenja između dva smGJC i dva konvencionalna GJC. SEM analizom uočen je značajno manji stepen mikrocurenja kod smGJC. Sidu (*Sidhu*) [17] je ispitivao adheziju za dentin dva svetlosno-polimerizujuća GJC: Fuji II LC i VariGlas VLC. Zubi su metodom slučajnog izbora svrstani u tri grupe: zubi kontrolne grupe su restaurisani hemijski polimerizujućim GJC – Fuji Cap II, dok su zubi iz preostale dve grupe restaurisani materijalima Fuji II LC i VariGlas VLC. Srednja vrednost zjapa zabeležena kod uzoraka kontrolne grupe bila je 26 µm, dok je kod uzoraka eksperimentalnih grupa bila 8 µm (Fuji II LC) i 10 µm (VariGlas VLC). Gledis (*Gladys*) i saradnici [18] su upoređivali rubno zatvaranje dva kompozitna materijala, jednog kompomera, dva konvencionalna GJC i tri smGJC. Kod svih ispitivanih materijala uočene su mikropukotine, a najmanja je bila kod smGJC. Slične rezultate su dobili i Šedin (*Sjödin*) i saradnici [19], koji su zaključili da je stepen mikrocurenja manji kod smGJC i kompomera, nego kod konvencionalnih GJC. Gupta (*Gupta*) i saradnici [20] su ispitivali mikrocurenje kod kompozitnih restauracija sa konvencionalnim GJC i smGJC kao podlogom. Bolji rezultat, odnosno manji stepen mikrocurenja zabeležen je na zubima kod kojih je kao podloga korišćen smGJC. Kastro (*Castro*) i saradnici [21] su poredili stepen mikrocurenja kod Fuji IX, Fuji II (konvencionalni GJC), Vitremera (smGJC) i kompozita. Rezultati njihove studije su pokazali da je Fuji II imao veći stepen mikrocurenja od svih ostalih ispitivanih materijala.

Podaci iz literature ukazuju na činjenicu da je uzrok nastanka mikropukotine kompleksne prirode i da se kod svih restaurativnih materijala mikropukotina javlja u određenoj meri, ali da je ona najmanja kod smGJC. Osnovni razlozi za ove tvrdnje su u činjenici da GJC u odnosu na ostale restaurativne materijale imaju najusklađeniji koeficijent termičke ekspanzije i razvijaju, pre svega, hemijsku vezu sa tvrdim zubnim tkivima [3, 22, 23]. Međutim, ne smeju se zanemariti ni podaci dobijeni na osnovu testova zamora, čime je utvrđeno da svi restaurativni materijali izloženi cikličnom opterećenju trpe pad otpornosti na lomljenje (razvoj pukotina) [24]. Ta otpornost kod klasičnih i hibridnih jonomera je slična vrednostima kompozita sa mikropunilom. Vrednosti kod kompomera su slične hibridnim kompozitima u početnoj fazi, ali s većom učestalošću dejstva sile, glasjonomerna svojstva materijala nadvladavaju kompozitna.

ZAKLJUČAK

Na osnovu dobijenih rezultata može se zaključiti da je bolja adhezivna veza sa tvrdim zubnim tkivima ostvarena primenom GJC Fuji II LC modifikovanog smolom. SEM analiza je ukazala i na manju vrednost mikropukotine kod ove vrste GJC u odnosu na klasičan GJC Fuji II.