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Ante Miličević[1], Kristina Goršeta[1], Raimond NV van Duinen[2], Domagoj Glavina[1]

Površinska hrapavost staklenoionomernih cementa nakon primjene različitih tehnika poliranja

Surface Roughness of Glass Ionomer Cements after Application of Different Polishing Techniques

[1] Zavod za dječju i preventivnu stomatologiju Stomatološkog fakulteta Sveučilišta u Zagrebu
Department of Pedodontics and Preventive Dentistry, School of Dental Medicine University of Zagreb
[2] Privatna stomatološka ordinacija, Hague, Nizozemska
Private Dental Clinic, Hague, Netherlands

Sažetak
Staklenoionomerni cementi često se primjenjuju u kliničkoj praksi zbog niza pozitivnih svojstava – kemijskog vezivanja na tvrda zubna tkiva, otpuštanja fluorida, koeficijenta toplinske ekspanzije sličnih koeficijentu zuba, ne zahtijevaju potpuno suho radno polje, manje su volumetrijske kontrakcije te zadržavaju dobru stabilnost boje. Fizička svojstva mogu se poboljšati upotrebom vanjske energije kao što su ultrazvuk i toplina koji ujedno ubrzavaju kemijski proces stvrdnjivanja. **Svrha:** Željela se usporediti hrapavost površine staklenoionomernih cementa tretiranih grijanjem (engl. *thermo-curing*) i bez grijanja te ustanoviti koja je tehnika poliranja učinkovitija. **Materijali i metode:** Dva polirajuća sustava (volfram-karbidna svrdla i diskovi Sof-Lex) korištena su za dvije vrste staklenoionomernog cementa (Equia Fil i Ketac Molar Universal). Uzorci tretirani grijanjem polimerizirani su s pomoću polimerizacijske LED svjetiljke Bluephase 16i (Vivadent, Schaan Lihtenštajn), a uzorci bez grijanja ostavljeni su 10 minuta kako bi se kemijski polimerizirali. Prosječna hrapavost površine (*Ra*) izmjerena je profilometrom. **Rezultati:** Rezultati istraživanja pokazali su za oba materijala najniže vrijednosti hrapavosti površine u kontrolnim skupinama s celuloidnom matricom. Pri primjeni materijala Equia Fil, uzorci tretirani grijanjem imali su niže vrijednosti prosječne hrapavosti površine (*Ra)* nakon poliranja diskovima Sof-Lex. Za uzorke materijala Ketac Molar Universala nisu zabilježene statistički značajne razlike ($p > 0,05$) između onih poliranih volfram-karbidnim svrdlima i diskovima Sof-Lex. **Zaključak:** Na temelju dobivenih rezultata može se zaključiti da najmanju hrapavost površine postižemo celuloidnom matricom (engl. *mylar strip*). Grijanjem materijala kod nekih vrsta staklenoionomernog cementa može se postići bolja poliranost površine.

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Adresa za dopisivanje
Prof. dr. sc. Domagoj Glavina
Sveučilište u Zagrebu Stomatološki fakultet
Zavod za dječju i preventivnu stomatologiju
Gundulićeva 5, HR-10 000 Zagreb
tel: 1 4802110
glavina@sfzg.hr

Ključne riječi
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Uvod

Staklenoionomerne cemente razvili su 1970. godine Wilson i Kent (1). U širokoj su primjeni u kliničkoj praksi zbog niza pozitivnih svojstava – kemijskog vezivanja na tvrda zubna tkiva, otpuštanja fluorida, koeficijenta toplinske ekspanzije sličnog koeficijentu zuba, ne zahtijevaju potpuno suho radno polje, manje su volumetrijske kontrakcije te zadržavaju dobru stabilnost boje (2, 3).

Završavanje restauracije (engl. *finishing*) postupak je definiran kao ukupno oblikovanje ili redukcija morfologije restauracije kako bi se postigla idealna anatomija. Poliranje (engl. *polishing*) smanjenje je površinske hrapavosti i ogrebotina nastalih tijekom završnog postupka restauracije (4). Zaostala hrapavost površine može rezultirati upalom gingive, kolonizacijom bakterija, povećanom akumulacijom plaka i promjenom boje. Zato su ispravno završavanje i poliranje bitni postupci u restaurativnoj stomatologiji jer na taj način povećavamo estetiku i trajnost restauracije (5–7). Površinske ka-

Introduction

Glass Ionomer Cements (GICs) were introduced by Wilson and Kent in 1970 (1). They have been widely used in clinical practice because they possess a wide range of positive characteristics: chemical bonding to the tooth surface, fluoride release, the heat-expansion coefficient similar to the tooth, do not require an absolutely dry working area, less volumetric contraction, good color stability (2, 3).

Finishing is defined as shaping of teeth morphology with instruments to achieve ideal anatomy. Polishing eliminates the scratches resulting from finishing instruments and reduces surface roughness (4). Residual surface roughness may result in gingival inflammation, bacterial colonization, increased surface staining and dental plaque accumulation. Finishing and polishing are mandatory steps in restorative dentistry that enhance both longevity of restorations and esthetics (5-7). Surface characteristics and wear resistance of restorations are important criteria to predict the clinical deterakteristike i otpornost na trošenje materijala među važnijim su kriterijima za određivanje i predviđanje kliničke trajnosti restaurativnog ispuna. Slabije polirana i hrapava površina povećava sklonost prema bržoj kolonizaciji bakterija i nakupljanju plaka, što posljedično povećava opasnost od upale gingive i karijesa. Istodobno, visoko polirana površina smanjuje te rizike i pridonosi boljoj estetici i stabilnosti boje (8–12).

Autori nekih znanstvenih istraživanja izvijestili su o najnižim vrijednostima hrapavosti površine staklenoionomernih cementa nakon upotrebe celuloidne matrice. Nažalost, njezino korištenje ograničeno je zbog kompleksnosti anatomije zuba (13–16). Bollen i suradnici istražili su i istaknuli da granična vrijednost hrapavosti površine (Ra) za bakterijsku kolonizaciju iznosi 0,2 µm. Površine s vrijednošću hrapavosti većom od 0,2 µm imaju značajno veću mogućnost za bakterijsku kolonizaciju, sazrijevanje dentalnoga plaka i kiselost, čime se povećava rizik od karijesa (17). Zato je ispravno poliranje važan postupak u izradi ispuna jer povećava njegovu estetiku i trajnost te je izravno povezano s trošenjem i marginalnim integritetom restauracije (18, 19).

Hrapavost površine zapravo je mikrostruktura stvorena serijom fizikalnih i kemijskih procesa koji preinačuju površinu. Najčešći parametar za opisivanje hrapavosti površine jest srednja hrapavost (*Ra)* koja se mjeri profilometrom. Profilometri daju ograničene dvodimenzionalne informacije, pa su za potpunu sliku potrebne detaljne analize skenirajućim elektronskim mikroskopom (SEM-om). No za svaki materijal može se izračunati aritmetički prosjek hrapavosti površina, odnosno njihovih poliranih površina, koji može pomoći kliničaru pri odabiru restaurativnog materijala i polirnog sredstva (20–24).

Acido-bazna reakcija neutralizacije staklenoionomernih cementa može se ubrzati eksternom energijom, kao što su ultrazvuk (25–26) i toplina (27–28). To je posebno korisno za prevladavanje osjetljivosti na vlagu koja štetno utječe na svojstva staklenoionomernog cementa (29–31). Iako ultrazvuk ubrzava stvrdnjivanje, njegova je klinička primjena komplicirana. Istodobno, toplina se može postići LED svjetiljkom. Danas su na tržištu dostupni komercijalni staklenoionomerni cementi s uputama proizvođača za primjenu tehnike termičkog stvrdnjivanja (engl. *thermo-curing*) korištenjem radijacijske topline iz prenosive LED svjetiljke (32). Postojala je zabrinutost da takva izloženost toplini može potaknuti patološke promjene u pulpi tkiva. Van Duinen i suradnici dokazali su da korištenje eksterne topline tijekom stvrdnjivanja staklenoionomernog cementa nema kao posljedicu štetno pregrijavanje pulpnog tkiva ni patološki učinak. Naprotiv, primjena eksterne topline može se preporučiti u kliničkoj praksi kao tehnika za poboljšanje mehaničkih svojstava i adhezije staklenoionomernog cementa (3).

Svrha ovog istraživanja bila je analizirati učinak sredstava za poliranje na stupanj hrapavosti površine staklenoionomernog cementa te ustanoviti razlike u kvaliteti poliranja staklenoionomernog cementa tretiranog grijanjem i bez primjene grijanja. Nulta hipoteza ovog istraživanja jest da se primjenom tretmana grijanja staklenoionomernog cementa dobiva manja hrapavost površine.

rioration of restorative materials. Poorly polished and rough surfaces contribute to a faster accumulation of dental plaque and bacteria, which increases the gingival inflammation and caries risk. Conversely, a highly polished surface minimizes it and contributes to better esthetics and color stability (8-12).

Several articles have reported that the lowest roughness of GIC surfaces was found after treatment with the Mylar strip. However, the correct morphology of the restoration is rarely achieved by using only the Mylar strip (13-16). Bollen *et al*. reported that the critical surface roughness (Ra) for bacterial colonization is 0.2 µm. Bacterial accumulation, plaque maturation and acidity significantly increase when the surface roughness exceeds 0.2 µm, which acts on material surfaces, thus increasing caries risk (17). For that reason, finishing and polishing are necessary steps in restorative dentistry that enhance longevity of restorations and esthetics. Additionally, surface roughness can directly affect marginal integrity and the wear behavior of restoration (18,19).

Surface roughness is micromorphology created by various physical processes used for surface modification. Average roughness (Ra) is the most commonly used parameter to describe surface roughness that is measured with a profilometer. Profilometers provide two-dimensional information, but a scanning electron microscope (SEM) is needed for a complete picture of a detailed analysis. An arithmetic average roughness that can assist clinicians in their treatment decisions can be calculated for each material after polishing treatment (20-24).

The acid base neutralization reaction of GIC can be accelerated by the use of external energy such as ultrasound (25,26) and heat (27,28). This is particularly useful in overcoming the moisture sensitivity which adversely affects the properties of GIC material (29-31). Although ultrasound accelerated the setting, its use was clinically difficult. On the other hand, heat can be applied through portable LED lamps. Commercial Glass Ionomer Cements are now available on the market with manufacturer's instructions for applying *thermo-curing* technique using radiant heat from portable LED lamps (32). There was a concern that such heat exposure could have a potentially harmful effect on the dental pulp. Based on the obtained results of Van Duinen *et al*, it could be concluded that the use of external heat during the setting of GIC material does not lead to harmful overheating of the pulp tissue; hence it does not cause any pathological conditions. On the contrary, for improving the adhesion of GIC material and mechanical properties, the application of external heat (*thermo-curing*) as a "Command set „method can be part of regular clinical practice (3).

The aim of this study was to analyze the effect of polishing instruments on surface roughness of GIC and to determine the differences in the quality of polishing of GIC treated with heat (*thermo-curing*) and without the application of heat treatment. The null hypothesis was that GIC treated with heat (*thermo-curing*) obtain the lower surface roughness value.

Materijali i metode

U istraživanju su korištene dvije vrste staklenoionomernog cementa – Equia Fil (GC korp., Tokio, Japan) i Ketac Molar Universal (3M ESPE, Seefeld, Njemačka). Svaka vrsta podijeljena je u tri skupine – onu tretiranu grijanjem, bez tretmana grijanjem i kontrolnu (tablica 1.).

Ukupno 60 uzoraka (10 iz svake skupine) pripremljeno je u standardiziranim gumenim kalupima dimenzija 2 x 2 x 10 mm te podijeljeno u 6 skupina. Svaki uzorak staklenoionomernog cementa strojno je zamiješan prema uputama proizvođača te unesen u kalup ručnim aplikatorom za kapsule. Na vrhu kalupa materijal je prekriven celuloidnom vrpcom na koju je postavljeno predmetno stakalce uz lagani pritisak kako bi izašao višak materijala. Uzorci koji nisu tretirani grijanjem ostavljeni su deset minuta kako bi se omogućio kemijski proces stvrdnjivanja staklenoionomernog cementa. Uzorci tretirani grijanjem polimerizirani su polimerizacijskom LED svjetiljkom Bluephase 16i (Vivadent, Schaan Lihtenštajn) pri intenzitetu od 1600 mW/cm^2. Tijekom grijanja vršak polimerizacijske svjetiljke bio je u doticaju s celuloidnom matricom kako bi se standardizirala udaljenost između polimerizacijskog svjetla i uzorka na debljinu celuloidne matrice. Svaki uzorak grijan je 20 sekundi na tri mjesta (u sredini i na krajevima) kako bi svi dijelovi cementa bili jednako zahvaćeni. Svi uzorci bili su tjedan dana pohranjeni u vazelinu (engl. *storage media*).

Nakon sedam dana uzorci su izvađeni te očišćeni alkoholom. Osim kontrolnih skupina, polovina uzoraka iz svake eksperimentalne skupine polirana je diskovima Sof-Lex uz vodeno hlađenje (3M ESPE, St. Paul, SAD), a druga polovica volfram-karbidnim svrdlima (Komet Dental, Brasseler GmbH & Co KG) (tablica 2.).

Svaki uzorak poliran je prema uputama proizvođača kad je riječ o brzini rotacije svrdala i vremenu aplikacije polirajućeg sredstva. Kako bi uzorci imali glatku površinu, polirnim sredstvima činili su se jednakomjerni i ravni pokreti slijeva nadesno. Sve uzorke pripremila je ista osoba kako bi se eliminirale individualne različitosti operatera i postigao jednak pritisak polirnog sredstva na uzorke staklenoionomernog cementa. Korištene su četiri gradacije diskova Sof-Lex (grubi, srednji, fini i ultra-fini) i tri gradacije volfram-karbidnih svrdala (plava, žuta i bijela). Nakon završenog procesa poliranja uzorci su 24 sata pohranjeni u destiliranu vodu. Kontrolne

Material and methods

Two types of GIC were used in this study, Equia Fil (GC Corp, Tokyo, Japan) and Ketac Molar Universal (3M ESPE, Seefeld, Germany). The specimens of each material were divided into three groups: treated with heat (*thermo-curing*) without heat and the control group (Table 1).

All 60 specimens were prepared using standardized rubber molds with dimensions 2x2x10mm and divided into six groups (n=10). Material for each sample was capsulated and mechanically mixed according to the manufacturer's instructions and inserted into the molds using a hand applicator for the capsules. The material was covered with a transparent Mylar strip on the top of the filled mold. A glass plate was placed against the top surface of the transparent Mylar strip and pressed with light pressure to expel the excess material from the mold. Bluephase 16i LED light (Vivadent, Schaan Liechtenstein) was used at an intensity of 1600 mW/cm^2 for the GIC specimens treated with heat *(thermo-curing)*. The samples without heat treatment were left for 10 minutes to chemically cure. During heating, the tip of the polymerization device was in contact with the Mylar strip to standardize the distance between the heat source and the sample on the thickness of the Mylar strip. The samples treated by thermo-curing were treated for 60 seconds in three places for 20seconds each (in the middle and at the ends of molds) so that all parts of the cement were equally affected. Subsequently, the prepared samples were stored in a petroleum jelly as a storage media for a week.

After seven days, the samples were cleaned with alcohol. Apart from control group, half of the samples of each experimental group, were polished with Sof-Lex discs system with water cooling (3M ESPE, St. Paul, USA), and the other half with Tungsten carbide drills (Komet Dental, Brasseler GmbH & Co KG) (Table 2).

Each sample was polished according to the manufacturer's instructions with respect to the speed of rotation of the spindle and the application time of the polishing agent. In order for the samples to have a smooth surface, the polishing was performed evenly and flatly from the left to the right direction. All samples were made by the same operator to eliminate individual operator differences and made equal pressure on the GIC samples. Four grades of Sof-Lex discs (rough, medium, fine, and ultra-fine) and three gradations of Tung-

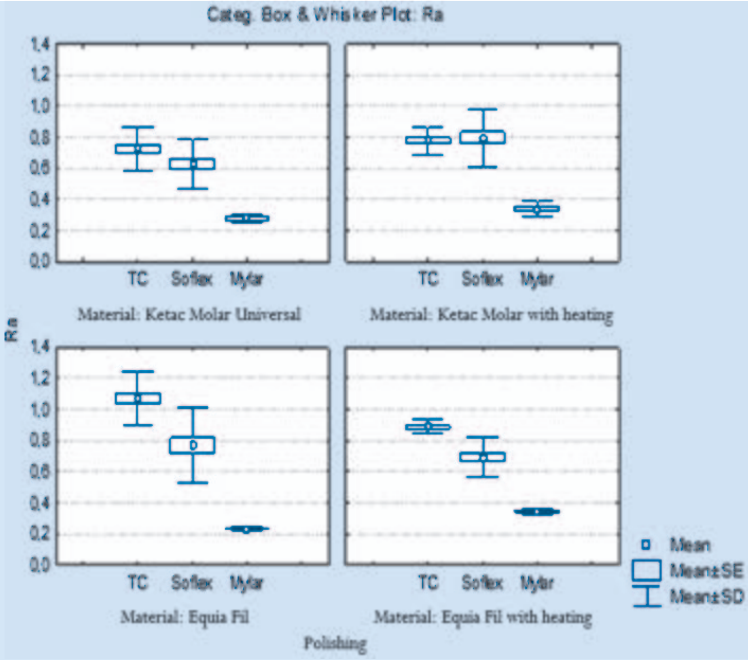
Tablica 1. Staklenoionomerni cementi podijeljeni u šest eksperimentalnih skupina
Table 1 GIC samples divided into six groups (n=10).

Skupina 1 • Group 1	Ketac Molar Universal - bez grijanja • without heat
Skupina 2 • Group 2	Ketac Molar Universal - s grijanjem • with heat (*thermo-curing*)
Skupina 3 • Group 3	Equia Fil - bez grijanja • without heat
Skupina 4 • Group 4	Equia Fil - s grijanjem • with heat (*thermo-curing*)
Skupina 5 • Group 5	Ketac Molar Universal - kontrolna skupina *(mylar strip – cel. mat.)* • control group *(Mylar strip)*
Skupina 6 • Group 6	Equia Fil - kontrolna skupina *(mylar strip – cel. mat.* • control group *(Mylar strip)*

Tablica 2. Polirna sredstva
Table 2 Polishing instruments.

Sof-Lex diskovi • Sof-Lex discs	3M ESPE, St. Paul, SAD • USA
volfram-karbidna svrdla • Tungsten-carbide drills	Komet Dental, Brasseler GmbH & Co KG

Slika 1. Mjerenje hrapavosti površine profilometrom
Figure 1 Surface roughness measurement with profilometer.



Legend: TC – Tungsten carbide drills; Soflex – Soflex discs; Mylar – the Mylar strip

Slika 2. Grafički prikaz prosječne vrijednosti hrapavosti površine (Ra) nakon obrade staklenoionomernog cementa diskovima Sof-Lex, volfram-karbidnim svrdlima i celuloidnom matricom *(mylar strip)*
Figure 2 Graphic presentation of average surface roughness (Ra) after treatment of GIC materials with Sof-Lex discs, Tungsten carbide drills and with the Mylar strip.

skupine nisu polirane. Polovica svake kontrolne skupine tretirana je grijanjem, a druga polovica nije.

Prije mjerenja hrapavosti površine (*Ra*), svi uzorci su osušeni. Hrapavost površine (*Ra)* izmjerena je profilometrom (KairDa, Kina) (slika 1.). Svaki uzorak izmjeren je na pet različitih mjesta te je uzeta prosječna vrijednost dobivenih rezultata. Svi rezultati podvrgnuti su statističkoj analizi. Korištene metode statističke analize bile su ANOVA (analiza varijance -analysis of variance) i Tukeyjev HSD test uz razinu značajnosti od 5 % ($p < 0,05$).

Rezultati

Na uzorcima staklenoionomernog cementa Ketac Molar Universal najmanja hrapavost površine izmjerena je u kontrolnoj skupini s celuloidnom matricom (eksperimentalna skupina 5). U kontrolnoj skupini nije bilo statistički značajne razlike ($p < 0,05$) između uzoraka tretiranih grijanjem i onih bez tretmana grijanjem. Rezultati dobiveni za eksperimentalne skupine 1 i 2 nakon poliranja uzoraka diskovima Sof-Lex i volfram-karbidnim svrdlima, u usporedbi tih dvaju polirnih sredstava, nisu pokazali statistički značajnu razliku ($p > 0,05$). Dakle, rezultati pokazuju da nema značajne razlike u odabiru između tih dvaju polirnih sredstava za tu vrstu staklenoionomernog cementa. Usporedba uzoraka poliranih diskovima Sof-Lex tretiranih grijanjem i uzoraka poliranih diskovima Sof-Lex bez grijanja, pokazuju manju hrapavost uzoraka tre-

sten carbide drills (blue, yellow and white) were used. After the completed polishing process, the samples were stored for 24 hours in distilled water. The control groups were not polished. Half of each control group was treated by thermo-curing and the other half without thermo-curing.

Prior to surface roughness measurement (Ra), all samples were dried. The surface roughness (Ra) was measured by a profilometer (KairDa, China) (Figure 1). Each sample was measured in five different places and the average value of the obtained results was taken. The obtained results were subjected to statistical analysis. The statistical analysis methods used were the analysis of variance (ANOVA) and the Tukey HSD test at a level of 95% significance ($p <0.05$).

Results

The specimens of GIC Ketac Molar Universal obtained smoothest surface roughness in the control group with the Mylar strip (experimental group 5). There were no statistically significant differences ($p <0.05$) between the samples treated with a heat (*thermo-curing*) and samples without heating treatment within the control groups. The results obtained for the experimental groups 1 and 2 after polishing the samples with Sof-lex discs system and Tungsten carbide drills did not show a statistically significant difference ($p> 0.05$) in the mutual comparison of these two polishing agents. Thus, the results indicate that there were no significant differences in the choice between these two polishing agents for this type of GIC. A comparison of samples polished with Sof-lex discs with thermo-curing and without thermo-curing showed tiranih bez grijanja. Rezultati dobiveni testiranjem uzoraka poliranih volfram-karbidnim svrdlima tretiranih grijanjem i uzoraka bez grijanja nisu pokazali statistički značajnu razliku (p > 0,05) (tablica 3.).

Uzorci staklenoionomernog cementa Equa Fil imali su najmanju hrapavost površine u kontrolnoj grupi s celuloidnom matricom (eksperimentalna skupina 6). U kontrolnoj skupini nije bilo statistički značajne razlike (p > 0,05) između uzoraka tretiranih grijanjem i onih bez tretmana grijanjem. U eksperimentalnim skupinama 3 i 4 uzorci polirani diskovima Sof-Lex ostvarili su bolje rezultate u odnosu prema uzor-

the lower roughness values than the samples treated without thermo-curing. The results obtained by testing samples of polished Tungsten carbide drills treated with thermo-curing and non-heating samples showed no statistically significant differences (p> 0.05) (Table 3).

The specimens of GIC Equia Fil obtained the smoothest surface roughness in the control group with the Mylar strip (experimental group 6). Within the control groups, there were no statistically significant differences (p <0.05) between the samples treated with thermo-curing and the samples without thermo-curing. In the experimental groups 3 and 4,

Tablica 3. Prosječna hrapavost površine (Ra) za staklenoionomerni cement Ketac Molar Universal
Table 3 Average surface roughness (Ra) for Ketac Molar Universal

Materijal • Material	Poliranje • Polishing instrument	N	Ra	Std.Dev	min	max
Ketac Molar U. bez grijanja • without heating	volfram-karb. • Tungs-carb	10	0,727800	0,138397	0,563000	0,992000
	Sof-Lex	10	0,629609	0,162293	0,372000	0,851000
	cel. mat. • Mylar	10	0,277200	0,021091	0,244000	0,308000
Ketac Molar U. + grijanje • with heating	volfram-karb. • Tungs-carb	10	0,779300	0,086876	0,643000	0,988000
	Sof-Lex	10	0,795280	0,190414	0,606000	1,129000
	cel. mat. • Mylar	10	0,342100	0,054803	0,287000	0,399000

Tablica 4. Prosječna hrapavost površine (Ra) za staklenoionomerni cement Equia Fil
Table 4 Average surface roughness (Ra) for Equia Fil

Materijal • Material	Poliranje • Polishing instrument	N	Ra	Std.Dev	min	max
Equia Fil – bez grijanja • without heating	volfram-karb. • Tungs-carb	10	1,070320	0,175747	0,717000	1,332000
	Sof-Lex	10	0,767240	0,241597	0,469000	1,206000
	cel. mat. • Mylar	10	0,233300	0,010499	0,215000	0,246000
Equia Fil + grijanje • with heating	volfram-karb. • Tungs-carb	10	0,886480	0,045677	0,812000	0,967000
	Sof-Lex	10	0,694400	0,125892	0,441000	0,849000
	cel. mat. • Mylar	10	0,344000	0,023132	0,312000	0,378000

Tablica 5. Analiza varijance (ANOVA) prosječne površinske hrapavosti (Ra) GIC sa i bez grijanja nakon poliranja tungsten karbidnim brusilima i Sof-lex diskovima
Table 5 ANOVA of the surface roughness (Ra) of GIC materials with and without heating treatment after polishing with Tungsten carbide drills and Sof-Lex discs.

	• SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
Ra	11,38404	11	1,034913	4,581942	216	0,021213	48,78743	0,00

Tablica 6. Tukey HSD post hoc test prosječne površinske hrapavosti (Ra) GIC sa i bez grijanja nakon poliranja tungsten karbidnim brusilima i Sof-lex diskovima
Table 6 Tukey HSD post hoc test of the surface roughness (Ra) of GIC materials with and without heating treatment after polishing with Tungsten carbide drills and Sof-Lex discs.

	1	2	3	4	5	6	7	8	9	10	11	12
Ketac Molar Universal TC {1}		0,452503	0,000018	0,990591	0,895154	0,000018	0,000018	0,998473	0,000018	0,006571	0,999820	0,000018
Ketac Molar Universal Sof-Lex {2}	0,452503		0,000018	0,037246	0,004719	0,000028	0,000018	0,049597	0,000018	0,000018	0,952295	0,000031
Ketac Molar Universal cel. mat. {3}	0,000018	0,000018		0,000018	0,000018	0,997805	0,000018	0,000018	0,999948	0,000018	0,000018	0,997158
Ketac Molar grijanje TC {4}	0,990591	0,037246	0,000018		1,000000	0,000018	0,000018	1,000000	0,000018	0,370136	0,793916	0,000018
Ketac Molar grijanje Sof-Lex {5}	0,895154	0,004719	0,000018	1,000000		0,000018	0,000018	0,999943	0,000018	0,539377	0,470126	0,000018
Ketac Molar grijanje cel. mat. {6}	0,000018	0,000028	0,997805	0,000018	0,000018		0,000018	0,000018	0,881824	0,000018	0,000018	1,000000
Equia fil TC {7}	0,000018	0,000018	0,000018	0,000018	0,000018	0,000018		0,000018	0,000018	0,000508	0,000018	0,000018
Equia fil Sof-Lex {8}	0,998473	0,049597	0,000018	1,000000	0,999943	0,000018	0,000018		0,000018	0,142633	0,883241	0,000018
Equia fil Mylar {9}	0,000018	0,000018	0,999948	0,000018	0,000018	0,881824	0,000018	0,000018		0,000018	0,000018	0,868933
Equia fil grijanje TC {10}	0,006571	0,000018	0,000018	0,370136	0,539377	0,000018	0,000508	0,142633	0,000018		0,000683	0,000018
Equia fil grijanje Sof-Lex {11}	0,999820	0,952295	0,000018	0,793916	0,470126	0,000018	0,000018	0,883241	0,000018	0,000683		0,000018
Equia fil grijanje cel. mat. {12}	0,000018	0,000031	0,997158	0,000018	0,000018	1,000000	0,000018	0,000018	0,868933	0,000018	0,000018	

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cima poliranima volfram-karbidnim svrdlima. U usporedbi uzoraka poliranih volfram-karbidnim svrdlima manja hrapavost površine (Ra = 0,88) postignuta je u uzorcima tretiranima grijanjem u odnosu prema onima poliranima volfram-karbidnim svrdlima bez grijanja (Ra = 1,07). Uzorci obrađeni diskovima Sof-Lex koji su tretirani grijanjem ostvarili su nižu prosječnu hrapavost Ra (Ra =0,69) u odnosu prema uzorcima bez grijanja (Ra = 0,76), iako ustanovljena razlika nije bila statistički značajna (p > 0,05) (tablica 4., 5. i 6.).

Grafički prikaz prosječne hrapavosti površine (Ra) nakon obrade SIC materijala Sof-Lexovim sustavom diskova, volfram-karbidnim bušilicama i celuloidnom matricom (slika 2.).

Rasprava

Staklenoionomerni cementi u širokoj su upotrebi u dentalnoj medicini, posebno u pedodonciji zbog mnoštva dobrih svojstava. No slabija mehanička svojstva i smanjena otpornost na trošenje svrstavaju staklenoionomerne restauracije u manje trajne (32). Hrapavost površine SIC-ovih restaurativnih materijala ima nekoliko kliničkih implikacija i promjena na površinskoj morfologiji te je često određena kao mjera za trošenje/habanje materijala. Povećana hrapavost može biti predisponirajući čimbenik za mikrobnu kolonizaciju koja može povećati rizik od oralnih bolesti. Povećana hrapavost površine može također uzrokovati pogoršanje materijala (9, 33).

Bollen i suradnici odredili su graničnu vrijednost hrapavosti površine *(Ra)* većine dentalnih materijala za bakterijsku kolonizaciju koja iznosi 0,2 μm. Vrijednosti više od 0,2 μm sklonije su povećanoj adheziji dentalnog plaka i bakterija, što se na površinu materijala odražava kao povećani rizik od karijesa (17). No staklenoionomerni cementi to djelomično kompenziraju jer djeluju antikarijesno otpuštanjem fluorida koji se ugrađuju u rešetku hidroksiapatita te usporavaju procese demineralizacije i pridonose remineralizaciji (11, 17, 34). S kliničkog stajališta, povećana hrapavost površine restauriranog zuba uzrokuje veću akumulaciju plaka, sekundarni karijes, gingivitis i gubitak parodontnog pričvrstka te u konačnici restauracija gubi sjaj i boju te postaje estetski neprihvatljiva (35). Jedan od nedostataka današnjih staklenoionomera jest lošije poliranje u usporedbi s kompozitima, no noviji staklenoionomeri sve se više približavaju kvaliteti poliranja kompozitnih materijala.

Rezultate slične ovima u našem istraživanju istaknulo je i nekoliko autora u svojim studijama u kojima je ustanovljeno da najmanju hrapavost imaju površine staklenoionomernog cementa nakon tretiranja celuloidnom matricom (engl. *mylar strip*). No pravilna anatomija i morfologija ispuna rijetko se postiže samo korištenjem celuloidne matrice (36 – 37). U ovom istraživanju korišteni su diskovi Sof-Lex i volfram-karbidna svrdla. Kad je riječ o Ketac Molar Universalu, nije bilo statistički značajne razlike (p > 0,05) između tih dvaju polirnih sredstava, a za Equia Fil dobiveni su bolji rezultati za uzorke tretirane diskovima Sof-Lex. Rezultati potiču na razmišljanje – može li uspješnost poliranja ovisiti i o vrsti resta-

the samples polished with Sof-lex discs system yielded better results compared to samples polished with the Tungsten carbide drills. In the comparison of the samples polished with Tungsten carbide drills, the smoothest surface roughness (Ra = 0.88) was achieved with thermo-curing treatment samples compared to polished Tungsten carbide drills without thermo-curing treatment (Ra = 1.07). The samples polished with Sof-lex discs system treated with thermo-curing achieved a lower average roughness Ra (Ra = 0.69) compared to non-heated samples (Ra = 0.76), although the observed difference was not statistically significant (p > 0) (Table 4, 5 and 6).

Graphic presentation of average surface roughness (Ra) after treatment of GIC materials with Sof-Lex discs system; Tungsten carbide drills and with Mylar strips (Figure 2).

Discussion

Glass-ionomer cements (GICs) have been widely used in dental medicine, especially in pediatric dentistry due to a large number of good features. However, lower mechanical properties and reduced wear resistance put a GIC restoration into less durable restorations (32). Surface roughness of GIC materials has several clinical implications and changes in surface often defined as a measure of wear of materials. An increased roughness can be a predisposing factor for bacterial colonization that increases the risk of oral disease. Also, increased roughness of the surface can cause deterioration of the material (9, 33).

Bollen *et al.* reported that critical surface roughness (Ra) for bacterial colonization is 0.2 μm. Bacterial accumulation, plaque maturation and acidity significantly increase when the surface roughness exceeds 0.2 μm, which acts on material surfaces, thus increasing caries risk (17). However, GICs partially compensate for their anti-caries release of fluoride that is incorporated into the hydroxyapatite lattice and slow down the processes of demineralization and contribute to the remineralization process (11, 17, 34). From a clinical point of view, the increased surface roughness of the restored tooth surface causes accumulation of plaque, secondary caries, gingivitis and loss of periodontal attachment, and ultimately restoration loses its shine and color (35). One of the flaws of today's GIC is worse polishing properties than composites, but newer GICs are increasingly approaching the quality of polishing composite materials.

Several authors in their studies showed the results similar to this study that the lowest surface roughness of GICs materials was found in the surface in contact with the Mylar strip. However, a correct anatomy and morphology of filling is rarely achieved only by using the Mylar strip (36, 37). Sof-Lex disks system and Tungsten carbide drills were used in this study. Ketac Molar Universal did not show statistically significant differences (p> 0.05) between these two polishing agents, but Equia Fil material showed better results in samples treated with Sof-Lex disks. The results suggest that polishing performance may also depend on the type of restorative material and the particle size, as confirmed by Bala et *al.* (38).

Poor mechanical properties and reduced wear resistance to GICs materials represent a sort of clinical problem. Howurativnog materijala i veličini čestica, što su u svojem istraživanju potvrdili O. Bala i suradnici (38).

Slabija mehanička svojstva i smanjena otpornost na trošenje staklenoionomernog cementa svojevrsni su klinički problem. No postupkom grijanja staklenoionomernog cementa poboljšavaju se mehanička svojstva i kvaliteta adhezije. Alegra i suradnici u svojem su istraživanju dobili mnogo bolju adheziju staklenoionomernog cementa na caklinu nakon tretiranja cementa grijanjem vanjskom energijom (ultrazvučnom i toplinskom - LED svjetiljkom) (39). Kleverlaan i suradnici u istraživanju su dokazali značajno poboljšanje mehaničkih svojstava nakon tretmana grijanjem staklenoionomernog cementa. Čvrstoća staklenoionomernog cementa rasla je proporcionalno primljenoj energiji, dakle uzorci s najvišom temperaturom imali su najveću čvrstoću (40). Dodatno, Goršeta i suradnici dokazali su da se grijanjem staklenoionomernog cementra smanjuje mikropropuštanje i povećava rubna prilagodba (41). Rezultati ovog istraživanja pokazuju da se kod nekih staklenoionomernih cemenata primjenom tretmana grijanja može dobiti bolja kvaliteta poliranja površine. Takvi rezultati dobiveni su za uzorke stakenoionomernog materijala Equia Fil.

Zaključak

Na temelju dobivenih rezultata može se zaključiti da najmanju hrapavost površine postižemo celuloidnom matricom.

Nulta hipoteza ovog istraživanja nije u cijelosti potvrđena zato što je dio uzoraka postigao manju hrapavost površine nakon tretiranja grijanjem u skladu s pretpostavkom nulte hipoteze, a dio veću u odnosu prema uzorcima bez grijanja. Primjenom tretmana grijanja materijala za neke vrste staklenoionomernog cementa može se postići bolja poliranost površine.

Sukob interesa

Autori nisu bili u sukobu interesa.

ever, *thermo-curing* of GICs materials improves mechanical properties and adhesion quality. Alegra *et al.*, in his research, obtained a much better adhesion of GIC materials on the enamel after treatment of cement by heating with external energy (induction and thermal trough LED lamp) (39). Kleverlaan *et al.* in their research have demonstrated a significant improvement in mechanical properties after *thermo-curing* of GIC materials. The strength of the GIC materials grew proportionally to the received energy; hence the samples with the highest heating temperature had the highest strength (40). In addition, Goršeta *et al.* have proved that *thermo-curing* of GIC materials reduces micro-discharge and increases edge alignment (41). The results of this research show that some GICs can be treated by using external heat (*thermo-curing)* to obtain a better surface polishing quality. Such results were obtained with samples of Equia Fil GIC material.

Conclusions

Based on the obtained results it can be concluded that the smoothest surface roughness is achieved by the Mylar strip.

The null hypothesis of this study was not fully validated because part of the samples obtained less surface roughness after they had been treated by thermo-curing according to the assumption of the null hypothesis, and the part of them achieved greater surface roughness compared to the samples without heating. Some types of GICs can obtain better surface polishing with heat treatment of the material (*thermo-curing*).

Conflict of interest

None declared.

Abstract
Glass Ionomer Cements (GIC) have been widely used in clinical practice since they have a wide range of positive characteristics: chemical bonding to the tooth surface, fluoride release, a heat-expansion coefficient similar to the tooth, do not require an absolutely dry working area, less volumetric contraction, good color stability. Physical properties can be improved by using external energy such as ultrasound and radiant heat *(thermo-curing)*, which also accelerates chemical curing. **Objectives:** The aim of this study was to determine the most effective polishing technique and to compare the surface roughness of two Glass Ionomer Cements after treatment with heat *(thermo-curing),* and without heat treatment during the setting process. **Materials and methods**: Two polishing systems (Tungsten carbide burs and Sof-Lex discs) were used on two types of GIC (Equia Fil and Ketac Molar Universal). Bluephase 16i LED (Vivadent, Schaan Liechtenstein) light was used for the specimens treated with heat *(thermo-curin*g). Samples without heat treatment are left for 10 minutes to chemically cure. Surface profilometar was used for measuring the mean surface roughness value (*Ra*). **Results**: Group with Mylar strip (control group) of each material showed the lowest (*Ra*) value. The Equia Fil material samples treated with heat (*thermo-curing*) achieved lower surface roughness values (Ra), and showed lower surface roughness values (Ra) after polishing with a Sof-Lex discs ($p<0.05$). The results for Ketac Molar Universal samples showed no statistically significant difference ($p>0.05$) between polishing with Sof-Lex discs and Tungsten carbide burs. **Conclusion**: Based on the obtained results, it can be concluded that the smoothest surface roughness is achieved by the Mylar strip. Some types of Glass Ionomer Cements can obtain better surface polishing with heat treatment *(thermo-curing)*.

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Address for correspondence
Professor Domagoj Glavina
University of Zagreb
School of Dental medicine
Department of Pedodontics and Preventive Dentistry
Gundulićeva 5, HR-10 000 Zagreb
Tel: +385 14802110
glavina@sfzg.hr

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Glass Ionomer Cements; Surface Properties; Adhesiveness; Heating; Dental Polishing

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