Fluoride release from conventional, resin-modified and hybrid glass ionomer cements

Maja Ležaja Zebić, Nikola Jakovljević, Vesna Miletić
University of Belgrade, School of Dental Medicine, Department of Restorative Odontology and Endodontics, Belgrade, Serbia

SUMMARY

Introduction The aim of the study was to quantify and compare fluoride release from four different glass ionomer cement products (GICs).

Materials and Methods Standardized disk-shaped samples (5x2mm; n=5/group) of GIC restorative materials: conventional (Fuji IX, GC Corp., Japan), resin-modified (Fuji II LC, GC) and hybrid glass ionomer cement (Equia Forte, GC) and a conventional GIC liner/base material (Alfagal, Galenika, Serbia) were tested for fluoride release up to 21 days post-setting. Each sample was immersed in 5 mL of fresh deionized water during each time interval. Universal microhybrid composite (Filtek Z250, 3M ESPE, USA) and adhesive (Adper Single Bond, 3M ESPE) were used as negative controls. Fluoride release was measured using an F-selective electrode (Cole-Parmer, USA) and an ion meter (Oakton 700, Cole-Parmer, USA). Data were statistically analyzed using one-way ANOVA, regression and correlation analysis at 0.05.

Results The highest total fluoride release was measured from Alfagal (386±61 ppm/g), and significantly less from Equia (188±29 ppm/g), Fuji IX (143±11 ppm/g) and Fuji II LC (104±14 ppm/g) (p < 0.05). All GICs showed the highest fluoride release during the first 24 hours post-setting. After 3 days, fluoride release slowed down reaching a plateau for all materials. Regression and Pearson correlation analysis showed significant inverse relationship between fluoride release and sample mass and density (p<0.001).

Conclusion Of the three GICs indicated for use as restorative materials, Equia Forte released the highest fluoride concentration. Fluoride release was material and density dependent, with higher release occurring from lower density GICs.

Keywords: fluoride; glass ionomer cements; glass hybrid; resin-modified glass ionomer

INTRODUCTION

One of the main reasons for restoration failure is secondary caries [1, 2, 3] which results in further tooth tissue loss, weakened remaining tooth structure or even premature tooth loss. Any mechanism that inhibits acid production by bacteria, increases resistance to demineralization or facilitates remineralization could be considered clinically significant. A recent study showed that the most commonly used restorative materials in contemporary restorative dentistry, resin-based composites, do not exhibit buffering potential, thus being more susceptible to the formation of secondary caries around such restorations [4].

Fluoride from fluoride-containing materials has the capacity to chemically interact with hydroxyapatite of enamel and dentin adjacent to the restoration resulting in the formation of fluorapatite [5, 6] which increases resistance to acid demineralization and prevents secondary caries [7, 8]. Fluoride released from fluoride-containing restorative materials, such as glass ionomer cements (GICs), may improve resistance to demineralization [9, 10], facilitate remineralization [11, 12] or even directly affect cariogenic bacteria by inhibiting their metabolic enzymes [13]. Fluoride was found in dentin, released from the bottom parts of GIC restorations (Fuji IX and Fuji II LC improved) in artificially demineralized monkey’s teeth after three days [14]. Fluoride-releasing materials show cariostatic properties and may affect bacterial metabolism under simulated cariogenic conditions in vitro [15].

GICs have been substantially improved over the years, especially their mechanical properties, thereby expanding indications for use. These improvements include the introduction of photopolymerizable resins (light-cured GIC), or ultrafine, highly reactive glass particles, dispersed within the conventional glass ionomer structure and a higher molecular weight polyacrylic acid in hybrid GIC. The latter has led to the recently launched hybrid GIC, Equia Forte, currently the only material in this ‘class’ of GICs.

It has been widely accepted that during the setting action of GICs a variety of ionic constituents is released from the glass phase, including fluoride. Fluoride is released in short-term by rapid dissolution from the outer surface of the set material into solution. Sustained ion release is the consequence of ion diffusion through the bulk cement. Despite the latest improvements, it is imperative that GICs maintain abundant fluoride release in order to support their anticariogenic potential.

The aim of the present study was to quantify and compare fluoride release from the conventional, resin-
modified and the new glass hybrid GICs into deionized water 1, 6, 24 h, 3, 7, 14 and 21 days post-setting. The null hypotheses were: (1) there is no significant difference in fluoride release from different GICs and (2) there is no significant relationship between fluoride release and sample mass/density.

MATERIALS AND METHODS

Details on the materials used in this study are given in the Table 1. All materials were used according to manufacturers’ instructions. Capsules of Fuji IX, Fuji II and Equia were mixed in an auto-mixer for 10 s. Alfagal was prepared by hand mixing 1 scoop of powder and 2 drops of liquid for 30 s using a plastic spatula on the paper pad. Z250 and Adper were used directly from the tube or bottle, respectively.

Standardized plastic molds, 5 mm in diameter and 2 mm deep, were placed on a Mylar strip and a glass pad, filled with GIC, composite or adhesive, covered with another strip, and pressed with a glass slide to extrude excess material and form smooth surfaces. Five samples were prepared per group, except the adhesive control group (Adper) with one prepared sample to avoid wasting material. Alfagal and Equia were allowed to set for 6 min and 2 min 30 s, respectively. Fuji II, Z250 and Adper were light-cured through the Mylar strip and 1 mm thick glass slide using a conventional LED light-curing unit (LEDi- tion, Ivoclar Vivadent, Schaan, Liechtenstein) operating at intensity of 800 mW/cm². Adper and Z250 were light-cured for 40 s, and Fuji II for 20 s each from the top and bottom side. Each sample was weighed on an analytical balance with an accuracy of 0.1 mg (ACCULAB ALC-110.4, Sartorius group, Goettingen, Germany).

All samples were stored dry for 24 h at 37°C. Following storage, each sample was immersed in 5 mL of deionised water in a sterile glass vial and kept at 37°C. Fluoride concentrations were measured after 1 h, 6 h, 24 h, 3, 7, 14 and 21 days using a F-selective electrode (Cole-Parmer, Bunker CT, Vernon Hills, Illinois) and an ion meter (Oakton pH/Ion 700 Bench Meter, Cole-Parmer, Bunker CT, Vernon Hills, Illinois). The electrode was first calibrated using 0.1, 1 and 10 ppm F. Ionic Strength Adjuster solution (0.5 mL) was added to all tested solutions just before measuring. Between measurements the electrode was rinsed with deionized water.

Statistical analysis was performed in Minitab 16 (Minitab Inc., State College, PA, USA). The data were analyzed using one-way ANOVA with Tukey’s post-hoc test for multiple comparisons at the level of significance alpha=0.05. Regression analysis and Pearson correlation were performed to determine the relationship between fluoride release and sample mass/density.

Table 1. Materials used in the study

| Material / Materijal | Type / Tip | Indications for use / Indikacije za upotrebu | Composition / Sastav |
|---------------------|-----------|--------------------------------------------|----------------------|
| ALFAGAL (Alfagal)   | Conventional glass ionomer cement / Konvencionalni GJC | Base material under composite or amalgam restorations | Liquid / Tečnost: 55% water solution of acrylic and itaconic acid copolymers. Powder / Prah: calcium-aluminium-barium-fluoro-silicate glass |
|                     | Galenika a.d. Belgrade, Serbia | For cementation of prosthodontic restorations and orthodontic rings | |
|                     | GC Corporation, Tokyo, Japan | For atramatous restorative treatment / Baza ispod kompozitnih ili amalgamskih ispuna, cementiranje protetnih nadoknada i ortodontskih bravic, atramatski restaurativni tretman | |
| GC Fuji IX GP CAPSULE (Fuji IX) | Conventional reinforced glass ionomer cement / Konvencionalni ojačani GJC | Final restorations (non-stress areas), Intermediate Restorative (IRM), core material and long-term, temporary restorations / Definitivni ispuni (zone van opterećenja), privremeni ispuni, dentinski zamenik | Liquid / Tečnost: Polyacrylic acid, water, polybasic carboxylic acid Powder / Prah: Aluminofluorosilicate glass, polyacrylic acid powder |
|                     | GC Corporation, Tokyo, Japan | | |
| GC Fuji II LC (Fuji II) | Light-cured resin-modified glass ionomer cement / Konvencionalni smolom modificovani GJC | Class III and V Restorations, cervical erosions/abfraction lesions and root surface caries liner/base / Ispuni III i V klase, cervicalne erozije/abfrakcije i karjers koarena, lajner/baza | Liquid / Tečnost: water, polyacrylic acid, HEMA Powder / Prah: fluorolaminosilicate glass, polyacrylic acid |
|                     | GC Corporation, Tokyo, Japan | | |
| EQUIA® Forte (Equia) | Conventional hybrid glass-ionomer cement / Konvencionalni hibridni GJC | Bulk fill glass hybrid restorative for Class I, II and V restorations / „Bulk fill” staklo-hibridni materijal za ispune I, II i V klase | Liquid / Tečnost: water, polybasic carboxylic acid, polyacrylic acid Powder / Prah: fluoro-aluminio-silicate glass, iron(III)-oxide |
|                     | GC Corporation, Tokyo, Japan | | |
| FiltekTM Z250 Universal Restorative (Z250) | Microhybrid composite / Mikrohibridni kompozit | All classes of restorations / Ispuni svih klasa | BisEMA6, UDMA, BisGMA, TEGDMA, silane-treated ceramic (75-85 wt%), benzotrizazol, EDMAB |
|                     | 3M ESPE, St. Paul, MN, USA | | |
| Adper Single Bond (Adper) | One-step self-etch adhesive system / Jednofazni samonagrizajući adhezivni sistem | Adhesive for composites / Adheziv za kompozite | Bis-GMA, HEMA, dimethacrylates, polyalkenoic acid copolymer, initiators, water and ethanol |
|                     | 3M ESPE, St. Paul, MN, USA | | |

HEMA – 2-hydroxyethyl methacrylate, Bis-EMA – ethoxylated bisphenol-A glycol dimethacrylate, UDMA – urethane dimethacrylate, Bis-GMA – bisphenol-A diglycidyl ether dimethacrylate, TEGDMA – triethylene glycol dimethacrylate, EDMAB – ethyl-4-dimethylamino benzoate
RESULTS

Aside from the control composite Z250, the mass and density of GIC samples varied significantly, with the conventional GIC Alfagal showing lower mass and density than other tested GICs (p<0.001) (Table 2).

Table 2. Mass and density of the tested materials per sample. Mean (standard deviation)

| Material / Materijal | Mass / Masa (mg) | Density / Gustina (mg/mm³) |
|----------------------|------------------|-----------------------------|
| Z250                 | 123.4 (4.9)^
A                       | 3.14 (0.13)^
A                       |
| Fuji II              | 117.2 (3.2)^
A                      | 2.98 (0.08)^
A                      |
| Fuji IX              | 113.0 (1.7)^
C                      | 2.88 (0.04)^
C                      |
| Equia                | 109.1 (2.8)^
C                      | 2.78 (0.07)^
C                      |
| Alfagal             | 94.7 (3.2)^
P                      | 2.41 (0.08)^
P                      |

In each column, the same upper-case letters indicate no statistically significant difference between groups (p > 0.05).

Fluoride release varied in concentration between materials and time periods (Figure 1). All GICs had the highest fluoride release during the first 24 h post-setting. Relatively high fluoride release occurred from GICs except Fuji II over the next 48 h (the first 3 days in total) as indicated by steep slopes in Figure 1. Further release was notable until the end of the experiment (21 days) with base/liner GIC Alfagal showing the highest fluoride release in all tested times (more than double the values of other materials) (p<0.05). Equia released more fluoride than Fuji IX and Fuji II with Fuji II releasing the least fluoride concentration of the tested GICs (p<0.05). Fluoride release in negative control groups, both composite Z250 and Adper adhesive, was 10 or more times lower compared to GICs (11.46±2.45 and 14.81 ppm per gram composite and adhesive, respectively, over 21 days).

Regression and Pearson correlation analysis showed significant inverse relationship between fluoride release (F) and sample mass and density (p<0.001) (Figure 2). The regression equations may be expressed as Equations 1 and 2:

\[ F = 132.00 - 1020.43 \times \text{Mass} \quad \text{Equation 1.} \]

\[ F = 132.00 - 40.072 \times \text{Density} \quad \text{Equation 2.} \]

with R-sq = 86.52% and R-sq(adj.) = 85.77%

Pearson correlation coefficient r≈-0.930 and p<0.001 indicate strong negative correlation between fluoride release and mass/density i.e. higher fluoride release occurred from lower density GICs.

DISCUSSION

Both null hypotheses were rejected as the results confirmed significant differences in fluoride release between GICs as well as an inverse relationship between fluoride release and sample mass and density.

In the present study, a range of GICs with different composition was tested, from the ‘classical’ GIC formulated Alfagal to reinforced conventional Fuji IX, resin-modified and light-curable Fuji II to the latest glass hybrid Equia. This choice was made to cover a wide range of different GIC compositions so as to ascertain a range of potential fluoride concentrations released over a period of 21 days.

There is a lack of standardization vis-à-vis sample size, shape, the type and quantity of immersion media as
well as data presentation in the current literature. Data comparison is often difficult due to these differences. The present results are expressed as the amount of fluoride released from 1 gram of material. Deionized water was used as the immersion medium as it is most often used in other studies and has been shown to facilitate more fluoride release than artificial saliva [16].

Short- and long-term fluoride release from restorative materials is related to their matrices, setting mechanisms and fluoride content and as well as environmental conditions [15]. The present results showed the highest fluoride release from the conventional GIC Alfagal. Alfagal has the most ‘classical’ GIC composition of all tested GICs, based on a water solution of acrylic and itaconic acid copolymers. It is of lower density (lower viscosity) than other tested GICs and is specifically indicated for use as a liner/base under direct and indirect restorations. Alfagal is not indicated as a filling (restorative) material, not even in non-load-bearing areas, in contrast to other tested GICs. It is well known that early, conventional GICs exhibit inferior mechanical properties than other filling materials and profound sensitivity to water imbalance, especially during the first 24 h [17]. Resin modification of the conventional formula led to somewhat improved mechanical properties but still below those of resin-based composites [18]. Also, GICs with higher powder-to-liquid ratio exhibit better mechanical properties [19]. Higher water uptake and solubility as well as less complicated internal structure compared to GICs containing high molecular polyacrylic and polybasic carboxylic acid and/or resin monomers may have led to more pronounced fluoride release from Alfagal than other tested GICs.

Equia had higher fluoride release compared to Fuji IX and Fuji II, but the difference was not statistically significant between Equia and Fuji IX, probably due to relatively high SD values. However, the results are indicative of a tendency of higher fluoride release from Equia than Fuji IX. These two GICs share a similar composition, and Equia is considered a successor of Fuji IX. Higher fluoride content, slightly lower density or other compositional modification undisclosed by the manufacturer could be the reason(s) for somewhat higher fluoride release from Equia than Fuji IX. In clinical practice it is recommended to cover the surface of Equia restorations with Equia Forte Coat, a light-curable resin-based liquid. This coat would probably act as a semipermeable membrane, allowing partial fluoride release into the oral environment. However, low wear resistance of unfilled or very low filled resin liquid indicates that protective coat would be worn during function leaving Equia exposed for unrestricted fluoride release. As the longevity of the coat layer in clinical conditions is unpredictable and individual, the present study design without any protective layer allowed measuring maximum fluoride release for the given sample size and shape.

Previous studies reported different findings related to fluoride release from resin-modified and conventional GICs. Several studies showed no significant difference in fluoride release between light-cured and conventional GICs [20, 21, 22]. The present study detected less fluoride release from light-cured Fuji II compared to other tested GICs. Fluoride release from resin-modified GICs could be hampered by the polymer network intertwined with polyalkeenoate chains.

Following the highest fluoride release during the first 24 h post-setting, fluoride release from each material decreased sharply over the first week and continued to decrease steadily over the 3 weeks period which is in agreement with other studies reporting the maximum release during the first 24–48 h [23–27]. In all GICs a tendency for fluoride release was observable based on the increasing slope in Figure 1. This indicated that new formulations of GICs also act as a pool of fluoride with potential continuous release over a long time, especially in environment with acidic pH. Earlier studies have shown a steady fluoride release over the period of 2 years from conventional GICs [28].

Continuous fluoride release was also detected in a rare in vivo study by Koch et al. [29] who showed that fluoride concentration in saliva immediately after placement of GIC restorations increased from 0.04 ppm to 0.8–1.2 ppm, but slowly decreased about 35 % after 3 weeks and additional 30 % after 6 weeks.

Although clinical importance of fluoride as an anticariogenic agent is nowadays generally accepted, the evidence to corroborate this statement comes from in vitro and in situ studies. Randomized clinical trials offer inconclusive evidence of greater caries protection by GICs [30]. Ex vivo studies showed the potential of fluoride ions to migrate from GIC restorations into the surrounding enamel and dentin of primary molars [31, 32]. Also, GICs were shown to inhibit secondary caries formation in vitro in artificial biofilm models [33, 34]. Until clinical evidence becomes definitive regarding the anticariogenic efficiency of fluoride-containing materials, primarily GICs, it is important that new and improved formulations of these materials maintain high levels of fluoride release.

CONCLUSION

Conventional, glass hybrid and resin-modified GICs showed continuous release of fluoride ions over 21 days after setting. Concentrations of released fluoride differed and were affected by material composition and density. The addition of resin into GIC formulation decreased its ability to release fluoride. Higher viscosity GICs could be also linked to lower fluoride release. Of the three GICs indicated for use as restorative materials, Fuji II LC, Fuji IX and Equia Forte, the highest fluoride release occurred from Equia Forte.

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Otpuštanje fluorida iz konvencionalnih, smolom modificovanih i hibridnih glas-jonomer cemenata

Maja Ležaja Zebić, Nikola Jakovljević, Vesna Miletić
Univerzitet u Beogradu, Stomatološki fakultet, Klinika za bolesti zuba i endodonciju, Beograd, Srbija

KRATAK SADRŽAJ
Uvod Cilj ovog istraživanja je bio da se kvantifikuje i uporedi otpuštanje fluorida iz četiri glas-jonomer cementa (GJC).

Materijal i metode Napravljeni su standardizovani diskovi (5 x 2 mm; n = 5/grupa) od sledećih GJC: konvencionalnih (Fuji IX, GC Corp., Japan), hibridni GJC (Equa Forte, GC) i konvencionalni GJC lajner/baza (Alfagal, Galenika, Srbija). Sispitano je otpuštanje fluorida tokom 21 dana tako što je svaki uzorka potapan u 5 ml sveže destilovane vode posle svakog mernog intervala. Univerzalni mikrohibridni kompozit (Filtek Z250, 3M EPSE, USA) i adheziv (Adper Single Bond, 3M ESPE) su kao negativne kontrole. Otpuštanje fluorida je očitavano pomoću fluor-selektivne elektrode (Cole-Parmer, USA) i jon-metra (Oakton 700, Cole-Parmer, USA).

Rezultati Ukupno otpuštanje fluorida je bilo najveće iz Alfagal (386 ± 61 ppm/g), značajno manje iz Equa Forte (188 ± 29 ppm/g), Fuji IX (143 ± 11 ppm/g), a najmanje iz Fuji II LC (104 ± 14 ppm/g) (p < 0,05). Svi GJC pokazali su najveće otpuštanje fluorida u toku prve 24 h po vezivanju. Posle tri dana otpuštanje fluorida je postajalo sporije dostažući plato za sva četiri materijala. Regresija i Pearsonova korelaciona analiza pokazale su značajan obrnut odnos između otpuštanja fluorida i mase i gustine uzoraka (p < 0,05).

Zaključak Odpredjeljenje fluorida iz konvencionalnih, smolom modificovanih i hibridnih GJC u destilovanoj vodi nakon 1, 6, 24 h i nakon 3, 7, 14, 21 dana od momenta vezivanja materijala. Nulte hipoteze su glasile: (1) nema značajne razlike u otpuštanju fluorida iz različitih vrsta GJC i (2) ne postoji značajna veza između otpuštanja fluorida i mase/gustine samih uzoraka.

MATERIJAL I METOD
Jedan od glavnih uzroka uspeha restauracije jeste njegova mineralizacija. Cilj ovog istraživanja je bio da se kvantifikuje i uporedi otpuštanje fluorida iz četiri glas-jonomer cementa (GJC).

Zaključak Pirsonova korelaciona analiza pokazale su značajan obrnut odnos između otpuštanja fluorida i mase i gustine uzoraka (p < 0,05). Svi GJC pokazali su najveće otpuštanje fluorida u toku prve 24 h po vezivanju. Posle tri dana otpuštanje fluorida je postajalo sporije dostažući plato za sva četiri materijala. Regresija i Pearsonova korelaciona analiza pokazale su značajan obrnut odnos između otpuštanja fluorida i mase i gustine uzoraka (p < 0,05).

MATERIJAL I METOD
Strogi kriteriji za izbor materijala za restauraciju zahvaljuju se na njegovim mehaničkim karakteristikama i kemijskom stvaralini. Cilj ovog istraživanja je bio da se kvantifikuje i uporedi otpuštanje fluorida iz četiri glas-jonomer cementa (GJC).

Zaključak Pirsonova korelaciona analiza pokazale su značajan obrnut odnos između otpuštanja fluorida i mase i gustine uzoraka (p < 0,05). Svi GJC pokazali su najveće otpuštanje fluorida u toku prve 24 h po vezivanju. Posle tri dana otpuštanje fluorida je postajalo sporije dostažući plato za sva četiri materijala. Regresija i Pearsonova korelaciona analiza pokazale su značajan obrnut odnos između otpuštanja fluorida i mase i gustine uzoraka (p < 0,05).
moću konvencionalne LED lampе (LEDition, Ivoclar Vivadent, Schaan, Lihtenštajn) iradijanse 800 mW/cm². Adper i Z250 su prosvetljavani po 40 s, a Fuji IX LC po 20 s sa gornje i sa donje strane uzorka. Masa svakog uzorka je merena na analitičkoj vagi sa preciznošću od 0,1 mg (ACCULAB ALC-110.4, Sartorius group, Goettingen, Nemačka).

Svi uzorci su ostavljeni da stoje 24 h na temperaturi od 37°C, posle čega je svaki uzorak potopljen u 5 ml destilovane vode u sterilnoj staklenoj bočici i čuvan na temperaturi od 37°C. Koncentracije fluorida merene su nakon 1 h, 6 h, 24 h, 3, 7, 14 i 21 dana pomoću fluor-selektivne elektrode (Cole-Parmer, Bunker CT, Vernon Hills, Illinois) i jon-metra (Oakton pH/Ion Koncentracije fluorida merene su nakon 1 h, 6 h, 24 h, 3, 7, posle čega je svaki uzorak potopljen u 5 ml destilovane vode group, Goettingen, Nemačka).

Testovke su ostavljene na jaku negativnu korelaciju između otpuštanja fluorida i mase/gustine uzoraka. Statistička analiza je urađena u statističkom programu Minitab 16 (Minitab Inc., State College, PA, USA). Podaci su analizirani jednofaktorskim ANOVA testom uz T ukey post-hoc testa za multiplu poredenja sa nivoom značajnosti α = 0,05. Regresiona i Pirsonova korelaciona analiza su primenjene kako bi se utvrdila veza između otpuštanja fluorida i mase/gustine uzoraka.

**REZULTATI**

Izuzev kontrolne grupe (Z250), masa i gustina GJC uzoraka je značajno varirala, pri čemu je konvencionalni GJC Alfagala pokazao manju masu i gustinu nego ostali testirani GJC (p < 0,001) (Tabela 2). Otpuštanje fluorida je variralo u koncentracijama između materijala i vremenskih intervala. (Grafikon 1). Svi GJC pokazali su najveće otpuštanje fluorida u prva 24 h posle vezivanja. Relativno visoko otponje fluorida se dešavalo i u sledećih 48 h (prva tri dana) sa izuzetkom Fuji IX LC, kao što se vidi u Grafikonu 1. Dalje otpuštanje fluorida je beleženo do kraja eksperimenta (21 dan), pri čemu je Alfagala baza/lajner pokazao najveće otpuštanje fluorida u svim ispitivanim vremenskim intervalima (više nego duplo u odnosu na druge materijale) (p < 0,05). Otpuštanje fluorida iz Equia Forte je bilo više nego iz Fuji IX i Fuji II LC, pri čemu je Fuji IX LC otpustio najmanju količinu fluorida od svih ispitivanih GJC (p < 0,05). Otpuštanje fluorida iz negativnih kontrolnim grupama, kompozit Z250 i Adper adheziv, bilo je deset i više puta manje u poredenju sa kontrolama (11,46 ± 2,45 i 14,81 ppm po gramu kompozita i adheziva tokom 21 dana).

Regresiona i Pirsonova korelaciona analiza su pokazale značajnu obrnutu vezu između otpuštanja fluorida (F) i mase/gustine (p < 0,001) (Figure 2). Regresione jednačine mogu biti predstavljene kao jednačine 1 i 2,

\[ F = 132,00 - 1020,43 \times \text{masa} \]

\[ F = 132,00 - 40,072 \times \text{gustina} \]

sa R-sq = 86,52% and R-sq(adj.) = 85,77%

Disokson korelacioni koečijent r = - 0,930 i p < 0,001 ukazuju na jaku negativnu korelaciju između otpuštanja fluorida i mase/gustine. GJC manje gustine otpuštali su veću količinu fluorida.

**DISKUSIJA**

Ob nulte hipoteze su odbačene, jer su rezultati potvrdili značajne razlike u otpuštanju fluorida između GJC, kao i obrnutu vezu između otpuštanja fluorida i mase/gustine uzoraka.

U ovoj studiji ispitano je više GJC različitog sastava, od „klaśično“ formulisanog GJC, Alfagala, ojačanog konvencionalnog Fuji IX, smolom modifikovanog i svetlosno polimerizujućeg Fuji II do GJC sa hibridnim staklenim punicijama, Equia. Ova izbor je napravljen kako bi se pokrio širok dijapazon različitih sastava GJC i kako bi se utvrdio opseg mogućeg otpuštanja fluorida tokom ispitivanog perioda od 21 dan.

U literaturi je primetno nedostaje standardizacije u smislu veličine i oblika uzorka, tipa i količine imerzionog medijuma, kao i u pretakacanost dobijenih podataka u trenutno dostupnoj literaturi. U početku dobijenih podataka je često teško zbog ovih različitosti. Zbog toga je u ovoj studiji otpuštanje fluorida normirano na jedan gram materijala. Destilovana voda je korišćena kao imerzijum medijum, po uguđu na druga istraživanja, jer je pokazano da više olakšava otpuštanje fluorida u odnosu na veštačku pljuvačku [16].

Kratkoročno i dugoročno otpuštanje fluorida iz restarativnih materijala je u vezi sa njihovim matriksom, mehanizmima vezivanja, količinom fluorida koje poseduju, a zavisí i od uslova okoline [15]. Rezultati našeg istraživanja pokazuju najveće otpuštanje fluorida iz konvencionalnog GJC Alfagala. Alfagala ima „klaśičniji“ sastav od svih testiranih GJC, Počiva na vodenom rastvoru akrilnih i itakonskih kiselinskih kopolimera. Manje je gustine (manje viskoznosti) od ostalih ispitivanih GJC i usko je indikovan za korišćenje kao lajner/baza ispod direktnih i indirektnih ispunja. Alfagala nije indikovan za ispune, čak i u regijama koje ne utiču velike praha nego tečnosti, imali su bojanje i mase/gustinu, a zavisi i od uslova okoline [16]. Rezultati ispitivanog perioda od 21 dana.

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bazi smole. Ovaj lak bi se verovatno ponašao kao semipermeabilna membrana, koja bi omogućila samo delimično otpuštanje fluorida u oralnu sredinu. Ipak, mala otpornost na trošenje smolastog laka koji u svom sastavu nema puniča bi značilo da bi lak mogao biti potrošen u funkciji žvakanja, što bi dovelo do direktnih izloženosti Equa oralnoj sredini i nesmetanom otpuštanju fluorida iz nje. Kako je dugotrajnost premaza u kliničkim uslovima nepredvidiva i individualna, u ovoj studiji je korišćena Equa bez zaštitnog laka kako bi se omogućilo merenje mogućeg maksimalnog otpuštanja fluorida iz ispitivanog uzorka.

Ranija istraživanja su pokazala različite podatke vezane za otpuštanje fluorida iz smolom modifikovanih i konvencionalnih GJC. Nekoliko studija su pokazale da ne postoji značajna razlika u otpuštanju fluorida između konvencionalnih i smolom modifikovanih GJC [20, 21, 22]. U ovoj studiji osoćeno je manje otpuštanje fluorida iz svetlosno polimerizujućeg Fuji II LC u odnosu na druge ispitivane GJC. Otpuštanje fluorida iz smolom modifikovanih GJC može biti otežano usled mreže polimera koja se prepliće sa poliakrilatnim lancima.

Posle najvećeg otpuštanja fluorida tokom prva 24 h od vezivanja, otpuštanje fluorida iz svakog materijala smanjilo je naglo tokom prve nedelje i nastavilo da se stanačno smanjuje tokom naredne tri nedelje. Posle istraživanja, ovaj materijal je smanjilo naglo koncentraciju fluorida iz mjesecima tokom prvih 24–48 h [23–27]. U svim ispitivanim GJC tendencija ka smanjenju fluorida je osmanjena prema povećanju nagiba u Grafikonu 1. Ovo ukazuje na to da su novije formulacije sastava GJC preplićena sa rezervoarom fluorida sa mogućim kontinuiranim otpuštanjem fluorida tokom dugog perioda, pogotovo u uslovima kiselog pH. Ranija istraživanja su pokazala stalno otpuštanje fluorida tokom dana iz konvencionalnih GJC [28].

Koncentracija fluorida je uočena i u retkoj in vivo studiji Kocha i sar. [29], koji su pokazali da količina fluorida u salivi neposredno posle postavljanja GJC ispunila raste sa 0,04 ppm na 0,8–1,2 ppm, ali lagano opada za oko 35% posle tri nedelje i dodatnih 30% posle šest nedelja.

Iako je klinička važnost fluorida kao antikariogenog činilca danas prihvaćena, dokazi koji potkrepljuju ovu tvrdnju dolaze iz in vitro i in situ studija. Randomizovana klinička ispitivanja nude nedovoljno dokaza o većem antikariogenom potencijalu GJC [30]. Ex vivo studije su pokazale potencijal fluoridnih jona da migriraju iz GJC ispunila u okolnu gled i dentin mlečnih molara [31, 32]. Takođe je pokazano da GJC inhibiraju nastanak sekundarnog karijesa in vitro u veštačkim biofilm modelima [33, 34]. U nedostatku konkluzivnih kliničkih dokaza, u smislu antikariogene efikasnosti materijala koji u svom sastavu sadrže fluor (na prvom mestu GJC), važno je da novije i unapređene formulacije ovih materijala zadrže visok nivo smanjenja fluorida.

ZAKLJUČAK
Konvencionalni, staklohibridni i smolom modifikovani GJC su pokazali kontinuirano otpuštanje fluorida tokom 21 dana od vezivanja. Koncentracije otpuštenih fluorida variraju i zavise od sastava materijala i njegove gustine. Dodatak smole u formulaciju GJC smanjuje mogućnost otpuštanja fluorida. Visokoznaji GJC mogli bi biti povezani sa slabijim otpuštanjem fluorida. Od tri GJC koji su indikovani kao materijali za ispunu (Fuji II LC, Fuji IX, Equia Forte), najveće otpuštanje fluorida je pokazala Equia Forte.

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Ovo istraživanje je podržano od strane projekta ON172007 Ministarstva prosvete, nauke i tehnološkog razvoja, Republike Srbije.