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# Effect of Polishing Systems on Fluoride Release and Surface Roughness of Different Restorative Materials

# El efecto de los sistemas de pulido en la liberación de flúor y rugosidad de diferentes materiales restauradores

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ABSTRACT: Secondary caries is an important factor in the replacement of the restorations, and it is thought that fluoride-releasing materials may prevent this problem. Furthermore, the fluoride release of the materials may be increased by polishing process. Available knowledge about the effect of polishing systems (PS) on the fluoride release of materials is limited. Therefore, this study was conducted to evaluate the effect of PS on the fluoride release of fluoride-containing materials. Restorative materials were divided into 6 groups: Fuji IX GP, Fuji II, Dyract XP, Beautifil II, Beautifil-Bulk, and Filtek Ultimate. Each group was also divided into four subgroups: Mylar strip, Sof-Lex Discs, Sof-Lex Diamond, and OneGloss. Fluoride release was determined using a fluoride ion-selective electrode. Surface roughness was evaluated with a profilometer. Two-way repeated measure and one-way ANOVA tests were used for statistical analysis. The initial rapid fluoride release was observed only in Fuji IX. The PS increased the fluoride release of Fuji IX and Fuji II and Dyract XP materials while reducing the fluoride release of resin-based materials. The highest surface roughness values were obtained with OneGloss. Further, a significant relationship between fluoride release and surface roughness was found. The polishing provides an increase in fluoride release, especially in glass-ionomer-based materials. This article revealed that there is a relationship between fluoride release and surface roughness. Proper PS must be chosen according to the material to provide the best clinical benefits in terms of fluoride release and surface roughness.

KEYWORDS: Compomers; Composite resins; Dental materials; Fluorides; Glass ionomer cements.

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RESUMEN: La caries secundaria es un factor importante para el reemplazo de restauraciones y se considera que los materiales que liberan flúor pueden prevenir este problema. Además, la liberación de fluoruro de estos materiales podría incrementarse mediante el proceso de pulido. El conocimiento disponible sobre el efecto de los sistemas de pulido (SP) en la liberación de fluoruro de los materiales es limitado. Por lo tanto, este estudio se realizó para evaluar el efecto de los SP sobre la liberación de fluoruro de materiales que contienen fluoruro. Los materiales de restauración se dividieron en 6 grupos: Fuji IX GP, Fuji II, Dyract XP, Beautifil II, Beautifil-Bulk y Filtek Ultimate. Cada grupo también se dividió en cuatro subgrupos: Banda Mylar, Discos Sof-Lex, Sof-Lex Diamond y OneGloss. La liberación de fluoruro se determinó usando un electrodo selectivo de iones fluoruro. La rugosidad de la superficie se evaluó con un perfilómetro. Se utilizaron medidas repetidas bidireccionales y pruebas ANOVA de una vía para el análisis estadístico. La liberación inicial rápida de fluoruro se observó solo en Fuji IX. El SP aumentó la liberación de fluoruro de los materiales Fuji IX y Fuji II y Dyract XP al tiempo que redujo la liberación de fluoruro de los materiales a base de resina. Los valores más altos de rugosidad de la superficie se obtuvieron con OneGloss. Además, se encontró una relación significativa entre la liberación de fluoruro y la rugosidad de la superficie. El pulido proporciona un aumento en la liberación de fluoruro, especialmente en materiales a base de ionómero de vidrio. Este artículo reveló que existe una relación entre la liberación de fluoruro y la rugosidad de la superficie. El SP adecuado debe elegirse de acuerdo con el material para proporcionar los mejores beneficios clínicos en términos de liberación de fluoruro y rugosidad de la superficie.

PALABRAS CLAVE: Compómeros; Resinas compuestas; Materiales dentales; Fluoruros; Cementos de ionómero de vidrio.

## INTRODUCTION

Glass-ionomer cements (GICs), also known as polyalkenoate cements, take their names from an acid base reaction between fluoride-containing aluminosilicate glass and polyalkenoic acid (1). They have been widely used and continuously developed since they emerged. The most important features of this material are that they provide moisture tolerance, have a coefficient of thermal expansion similar to dentin and have fluoride release, consequently anticariogenic properties (2). Some studies have reported that fluoride release from GICs makes demineralization of the surrounding dentin or enamel slower and may support the remineralization of lesions near the restoration wall (3,4). The calcium fluoroaluminosilicate glass of GICs reacts with a polyacid to release the fluoride ions. This release constitutes the protective and therapeutic effect of GICs and cause no adverse effects on the physical properties of the material (5). However, sensitivity to early moisture contamination, inadequate compressive strength, low wear resistance and fracture toughness are disadvantages of GICs (6,7). Furthermore, there are some studies suggesting that insufficient physical properties of the GICs are associated with an increased fluoride release (8). Therefore, it is still ongoing to investigate materials that maintain both physical properties and that can make a long-term fluoride release (9).

The most important factor in the failure and replacement of restorations is secondary caries

(10,11). It is thought that restorative materials that release fluoride may prevent or reduce this problem (12). In recent years, the use of fluoride-releasing materials has rapidly increased for the restoration of cavities and core build-ups (13). Other fluoride-releasing restorative materials than glass-ionomer are: resin-modified GICs, polyacid-modified composite resins (compomers), giomers, fluoride-containing composite resins and fluoride-releasing resin cements. These resin-based restorative materials have different fluoride sources (14,15), varying depending on the composition, solubility and permeability of the resin matrix in resin-based materials, as well as the source and concentration of the fluoride (15,16). On the other hand, finishing and polishing procedures are essential for the clinical success of restorations (17). The aesthetics and longevity of dental restorations are closely related to the quality of surface integrity and smoothness. The increased surface roughness may facilitate biofilm formation (18). In addition, a positive correlation was observed between surface roughness and bacteria adhesion (19) that support periodontal diseases, secondary caries, surface staining and disturbances due to the retention of bacterial plaques. (20,21). Furthermore, fluoride release may be increased by finishing and polishing of the outermost layer of the compomers (23). However, there are limited numbers of studies on the effects of polishing systems on the fluoride release of fluoride-containing materials (23,24). Therefore, the aim of this study is to evaluate the effects of two polishing systems on the fluoride release ability during a 28-day period and surface roughness of different restorative materials. The null hypothesis of this in vitro study is that the polishing system has no statistically significant effect on the amount of fluoride release.

## MATERIALS AND METHODS

### SPECIMEN PREPARATION

Six different restorative materials were included in this in vitro study. The compositions and manufacturers of the tested materials are given in Table 1. Disc shaped specimens were prepared for each restorative material tested (N=408). The specimens were prepared 5 mm in diameter and 2 mm thick for fluoride release tests (n=168) and 8 mm in diameter and 2 mm thick for the surface roughness tests (n=240). The test materials were loaded into a standard Teflon® mold and pressed between two opposing Mylar strips; they were then covered with a 1 mm thick glass slide to remove excess material and to obtain a smooth material surface. The conventional GIC specimens were allowed to auto-polymerize for 10 minutes. All other restoratives were light cured (1750 mW/cm2, Elipar Deep Cure, 3M ESPE) according to manufacturers' instructions. After the completion of the setting, the specimens were removed from the molds. The specimens used for the surface roughness test were kept in deionized water at 37°C for 24 hours before the polishing.

The prepared specimens were randomly divided into four subgroups according to the polishing system employed (Table 2). Mylar strip used as a control group. The specimens in the treatment group were wet-ground with 1200-grit silicon carbide paper for 60 seconds using a polishing machine (MetaServ, Buehler, IL, USA) at 600 rpm under water-cooling to standardize samples before the polishing process, and then the specimens were polished with low-speed handpiece as described in Table 2.

### MEASUREMENT OF FLUORIDE RELEASE

All specimens were transferred to polyethylene vials containing 3 ml of deionized water, separately (n=7). The solutions were kept in incubator at 37°C and thoroughly shaken at the time of the readings. The first measurement of the fluoride concentration was performed at 24 hours after the specimen preparation. After the reading, each sample was rinsed with 1 mL of deionized water and transferred to a new vial filled with 3 mL of fresh deionized water. Following the first measurement, fluoride measurement was repeated on days 2,3,4,5,6, 7,14,21 and 28. The fluoride concentration in these samples was analyzed using a fluoride ion selective electrode (9609 BN, Orion Research). The instrument (Orion 720A+) calibrated in accordance with the manufacturer's recommendations using six standard fluoride solutions containing 0.20, 1.00, 2.00, 10.00, 20.00 and 100 ppm F, respectively. Before measurement, 0.4 ml of TISAB III (940911, Orion Research) was added to each solution to provide constant background ionic strength. Then, the concentration of the specimens was calculated in parts per million (ppm) for comparison.

### MEASUREMENT OF SURFACE ROUGHNESS

The surface was evaluated using a surface analyzer (Surtronic 25, Taylor Hobson Limited, UK) to obtain average surface roughness. Each sample was measured at three indiscriminate areas and averaged to generate average roughness value (n=10), and were recorded in Ra, µm.

### STATISTICAL ANALYSIS

The means and standard deviations of the fluoride release and the Ra values were determined. Since the objective of this in vitro study not to make comparisons among different restorative materials, the fluoride release values of different materials were not compared with each other.

The fluoride release of the first week and weekly fluoride release was separately analyzed by two-way repeated measures ANOVA (factors: polishing and time). Surface roughness values were analyzed using one-way analysis of variance (ANOVA). Multiple comparisons were performed by the Tukey HSD test. The mean cumulative fluoride release within the 28 days for each material and the corresponding mean surface roughness were compared with the Spearman correlation test. All tests were performed by a statistical program (Prism 7, GraphPad Software, San Diego, CA, USA). Statistical differences at the $p<0.05$ level were considered statistically significant.

## RESULTS

The fluoride release of materials and their comparisons according to the polishing system and to each other are presented in Table 3. The highest amounts were detected during the first days, tending to decrease with time (Figures 1-6). When the first seven-day release values are examined, it is observed that different polishing methods have a significant effect on the amount of fluoride release ($p>0.05$). The polishing process increased the fluoride release of Fuji IX GP and Fuji II LC and Dyract XP materials while reducing the fluoride release of resin-based materials such as Beautifil II, Beautifil-Bulk and Filtek Ultimate ($p>0.05$). For the first three days, the fluoride release values of Fuji IX GP were almost doubled by the use of the polishing system.

A significant decrease was observed in the fluoride release of Fuji IX GP, Fuji II LC and Dyract XP materials after the first week, while the decrease in fluoride release of other materials was significant after the second week ($p>0.05$) (Table 3). Two-way repeated measures ANOVA revealed that time and polishing were statistically significant factors in fluoride release for all tested materials ($p>0.05$). Fluoride release of Fuji IX GP, Fuji II LC and Dyract

XP materials reached a constant threshold after the second week and no statistically significant difference was found between the third and fourth weeks ($p>0.05$). When the fluoride release was evaluated cumulatively, Fuji IV GP released more fluoride than other materials, while the least fluoride release was observed in Filtek Ultimate ($p<0.05$).

## SURFACE ROUGHNESS

Mean Ra values and standard deviations of six different restorative materials after different polishing systems are displayed in Table 4. Sof-Lex Discs polishing system in Fuji IX GP and Beautifil-Bulk groups produced less roughness than other polishing systems ($p<0.05$). In the Fuji II LC, Dyract XP, Beautifil II and Filtek Ultimate groups, there was no significant difference between Sof-Lex Discs and Sof-Lex Diamond. The highest surface roughness values of all other materials were obtained with OneGloss polishing system. There were no statistically significant differences between Sof-Lex Diamond and OneGloss for all groups, ($p>0.05$) except for Fuji IV.

The Pearson's correlation coefficient of 0.745 indicates a strong positive correlation between 28-day cumulative fluoride release and surface roughness ($r=0,745$; $p<0.05$).

**Table 1**. Material type, composition and manufacturer of the materials used.

| Material | Type | Composition and inorganic filler ratio |
|---|---|---|
| Fuji IX GP GC Tokyo, JAPAN | GIC | Polyacrylic acid, fluoroaluminosilicate glass, polybasic carboxylic acid.<br>Particle size: 10 µm. (70–80%). |
| Fuji II LC, GC Tokyo, JAPAN | Resin-modified GIC | Alumino-fluorosilicate glass, polyacrylic acid, 2- hydroxyethylmethacrylate, 2,2,4-trimethyl hexamethylenedicarbonate, triethylene glycol dimethacrylate.<br>Particle size: 5.9 µm. |
| Dyract XP, Dentsply, DeTrey, Konstanz, Germany. | Polyacid-modified composite resin (compomer) | UDMA, carboxylic acid modified dimethacrylate, TEGDMA, trimethacrylate resin (TMPTMA), dimethacrylate resins, camphorquinone, ethyl-4 (dimethylamino) benzoate, butylated hydroxy toluene (BHT), strontium-alumino-sodium-fluoro phosphor-silicate glass, highly dispersed silicon dioxide, strontium fluoride, iron oxide pigments and titanium oxide pigments.<br>Particle size: 0.8 µm. (73 wt.%, 47 vol%). |
| Beautifil II, Shofu, Kyoto, JAPAN | Giomer | BISGMA, TEGDMA, inorganic glass filler, aluminium oxide, silica, prereacted glass-ionomer filler, camphoroquinone.<br>Particle size: 0.8 µm, (83 wt.% 68.6 vol%). |
| Beautifil-Bulk, Shofu, Kyoto, JAPAN | Giomer | Bis-GMA, UDMA, Bis-MPEPP, TEGDMA, S-PRG filler based on fluoroboroaluminosilicate glass, polymerization initiator.<br>(87.0 wt.%, 74.5 vol%). |
| Filtek Ultimate, 3M ESPE, St Paul, MN, USA | Nanofill composite | Bis-GMA, UDMA, TEGDMA, poly(ethylene glycol) dimethacrylate (PEGDMA), Bis-EMA. (72.5 wt.%, 55.6 vol%).<br>Particle size: 20 nm silica particles, 4 - 11 nm zirconium particles. |

Bis-EMA: ethoxylated bisphenol-A dimethacrylate, Bis-GMA: Bisphenol A-glycidyl methacrylate, Bis-MPEPP: 2, 2'-Bis (4-Methacryloxy Polyethoxyphenyl), TEGDMA: Triethylene glycol dimethacrylate, UDMA: Urethane dimethacrylate, wt.%: weight percentage, vol%: volume percentage.

**Table 2**. Composition and application method of the polishing systems used.

| Polishing System | Composition | Application Method |
|---|---|---|
| OneGloss,<br>Shofu Inc., Kyoto,<br>JAPAN. | One-step olyvinylsiloxane finisher and polisher are mounted on mandrels ($Al_2O_3$, $SiO_2$) | OneGloss midi-points (ISO #060) were applied with light pressure on the discs for 20 s at low speed (10,000 rpm). The surfaces were then rinsed for 10 s. |
| Sof-Lex Discs,<br>3M ESPE, St. Paul,<br>MN, USA. | Aluminum oxide-coated disc.<br>Medium 40 µm,<br>Fine 24 µm, Ultrafine 8 µm. | The specimens were wet-polished with medium, fine and super-fine grits for 20 s at low speed (10,000 rpm). |
| Sof-Lex Diamond,<br>3M ESPE, St. Paul,<br>MN, USA. | Elastomer impregnated with aluminum oxide particles (25–29 µm). | Firstly, Sof-Lex medium discs were applied the surfaces of specimens.<br>A beige Sof-Lex Diamond finishing wheel was applied with light pressure for 20 s at low speed (10,000 rpm). Then, a white Sof-Lex Diamond polishing wheel was applied with light pressure for 20 s at low speed (10,000 rpm). The surfaces were rinsed for 10 s after each wheel used. |

**Table 3**. Fluoride release patterns of test materials (ppm ± SD).

| | Week 1 | Week 2 | Week 3 | Week 4 |
|---|---|---|---|---|
| **Fuji IX GP** | | | | |
| Mylar Band | $24.32 \pm 6.13^{aA}$ | $5,37 \pm 0,52^{aB}$ | $1,81 \pm 0,18^{ac}$ | $1,58 \pm 0,17^{ac}$ |
| S-Lex Disc | $39.66 \pm 3.20^{bA}$ | $6,41 \pm 0,48^{abB}$ | $2,01 \pm 0,36^{abc}$ | $1,78 \pm 0,22^{ac}$ |
| S-Lex Diamond | $39.94 \pm 2.18^{bA}$ | $7,48 \pm 1,67^{bB}$ | $2,22 \pm 0,24^{bcc}$ | $2,19 \pm 0,40^{bc}$ |
| One Gloss | $43.81 \pm 1.89^{bA}$ | $7,64 \pm 1,69^{bB}$ | $2,40 \pm 0,21^{cc}$ | $2,26 \pm 0,09^{bc}$ |
| **Fuji II LC** | | | | |
| Mylar Band | $20.82 \pm 0.83^{aA}$ | $5,68 \pm 0,31^{aB}$ | $3,28 \pm 1,07^{ac}$ | $3,31 \pm 0,20^{ac}$ |
| S-Lex Discs | $26.83 \pm 0.93^{bA}$ | $6,83 \pm 0,37^{bB}$ | $4,43 \pm 0,20^{bc}$ | $3,68 \pm 0,16^{abc}$ |
| S-Lex Diamond | $29.18 \pm 1.57^{cA}$ | $6,89 \pm 0,26^{bB}$ | $4,49 \pm 0,21^{bcc}$ | $4,50 \pm 1,45^{bc}$ |
| One Gloss | $31.56 \pm 1,22^{dA}$ | $7,88 \pm 0,38^{cB}$ | $4,49 \pm 0,21^{cc}$ | $4,22 \pm 0,21^{abc}$ |
| **Dyract XP** | | | | |
| Mylar Band | $10,40 \pm 0,56^{aA}$ | $4,01 \pm 0,40^{aB}$ | $1,62 \pm 0,10^{ac}$ | $1,95 \pm 0,14^{aD}$ |
| S-Lex Discs | $12,80 \pm 0,72^{bA}$ | $4,24 \pm 0,72^{baB}$ | $1,05 \pm 0,18^{ac}$ | $0,68 \pm 0,11^{bD}$ |
| S-Lex Diamond | $13,70 \pm 0,71^{cA}$ | $3,43 \pm 0,33^{cB}$ | $1,04 \pm 0,14^{ac}$ | $0,40 \pm 0,11^{bD}$ |
| One Gloss | $15,70 \pm 0,99^{dA}$ | $4,80 \pm 0,47^{bB}$ | $1,20 \pm 0,15^{ac}$ | $0,46 \pm 0,08^{bD}$ |
| **Beautifil II** | | | | |
| Mylar Band | $6,70 \pm 0,36^{aA}$ | $6,69 \pm 0,38^{aA}$ | $3,83 \pm 0,26^{aB}$ | $2,99 \pm 0,17^{ac}$ |
| S-Lex Discs | $4,07 \pm 0,34^{bA}$ | $1,90 \pm 0,30^{bB}$ | $2,64 \pm 0,28^{bc}$ | $1,85 \pm 0,16^{bB}$ |
| S-Lex Diamond | $3,83 \pm 0,38^{bcA}$ | $1,49 \pm 0,30^{bcB}$ | $2,11 \pm 0,38^{cc}$ | $1,71 \pm 0,15^{bB}$ |
| One Gloss | $3,42 \pm 0,14^{cA}$ | $1,24 \pm 0,14^{cB}$ | $1,91 \pm 0,07^{cc}$ | $1,50 \pm 0,05^{cB}$ |
| **Beauti Bulk** | | | | |
| Mylar Band | $5,88 \pm 0,31^{aA}$ | $5,79 \pm 0,57^{aA}$ | $3,30 \pm 0,38^{aB}$ | $2,82 \pm 0,17^{ac}$ |
| S-Lex Discs | $3,60 \pm 0,23^{bA}$ | $2,47 \pm 0,24^{bB}$ | $2,36 \pm 0,22^{bB}$ | $1,72 \pm 0,12^{bc}$ |
| S-Lex Diamond | $3,30 \pm 0,20^{bA}$ | $1,82 \pm 0,22^{cB}$ | $1,79 \pm 0,09^{cB}$ | $1,55 \pm 0,04^{cc}$ |
| One Gloss | $2,75 \pm 0,15^{cA}$ | $1,57 \pm 0,18^{cB}$ | $1,47 \pm 0,05^{cB}$ | $1,28 \pm 0,03^{dcB}$ |
| **F. Ultimate** | | | | |
| Mylar Band | $2,95 \pm 0,24^{aA}$ | $2,85 \pm 0,23^{aA}$ | $1,73 \pm 0,14^{aB}$ | $0,60 \pm 0,13^{ac}$ |
| S-Lex Discs | $1,73 \pm 0,11^{bA}$ | $1,25 \pm 0,14^{bB}$ | $1,17 \pm 0,08^{bB}$ | $0,35 \pm 0,03^{bc}$ |
| S-Lex Diamond | $1,57 \pm 0,08^{bcA}$ | $0,98 \pm 0,04^{cB}$ | $0,92 \pm 0,05^{cB}$ | $0,31 \pm 0,03^{bc}$ |
| One Gloss | $1,40 \pm 0,04^{cA}$ | $0,87 \pm 0,04^{cB}$ | $0,80 \pm 0,06^{cB}$ | $0,28 \pm 0,02^{bc}$ |

*Different superscript: lowercase for each column and uppercase for each row imply significant difference according to the two-way repeated measures ANOVA and Tukey HSD ($p<0.05$).

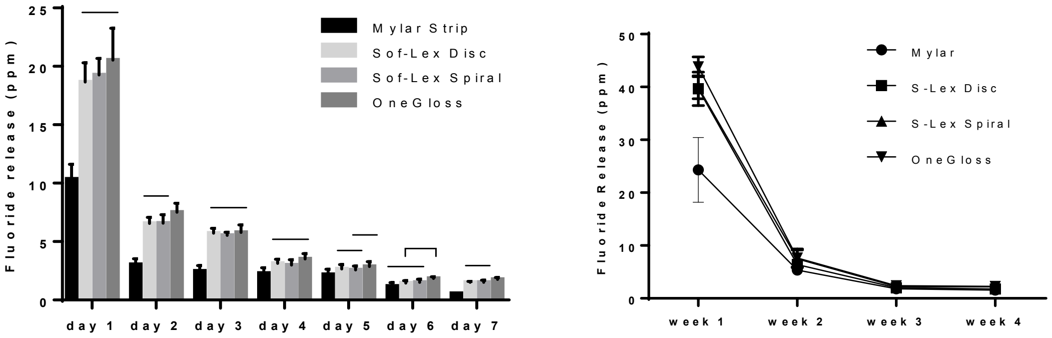

**Figure 1**. Mean fluoride release (ppm) of Fuji IV GP.

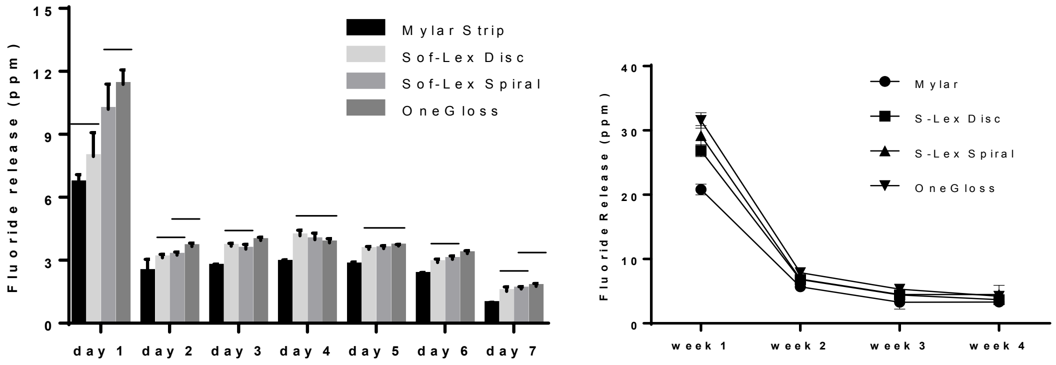

**Figure 2**. Mean fluoride release (ppm) of Fuji II LC.

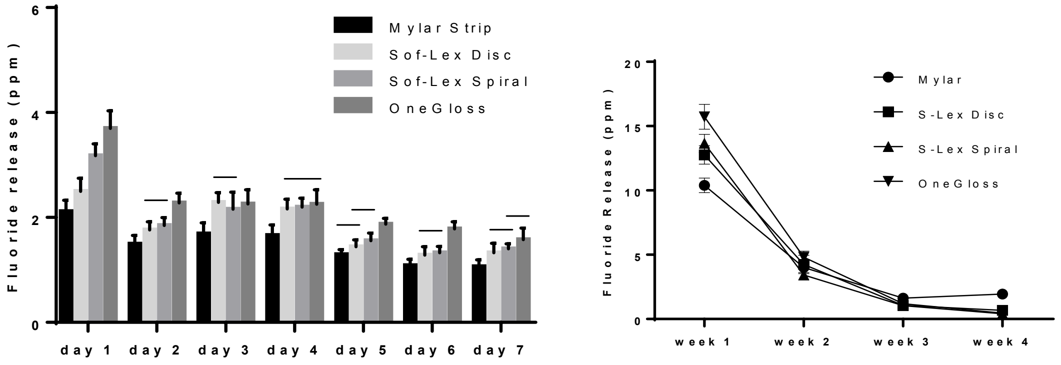

**Figure 3**. Mean fluoride release (ppm) of Dyract XP.

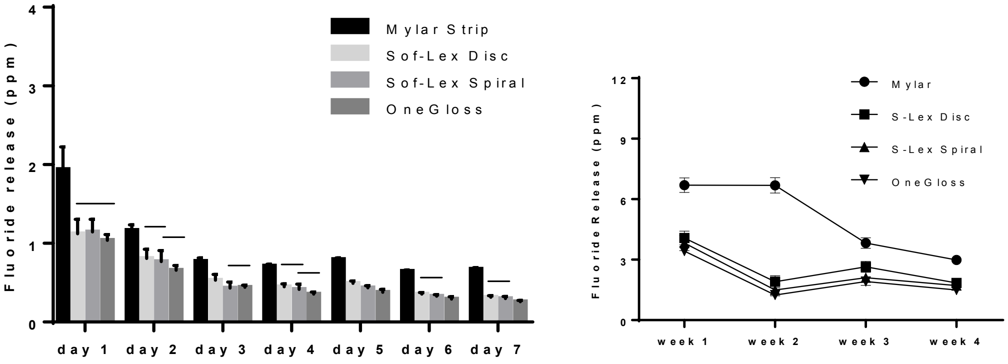

**Figure 4**. Mean fluoride release (ppm) of Beautifil II.

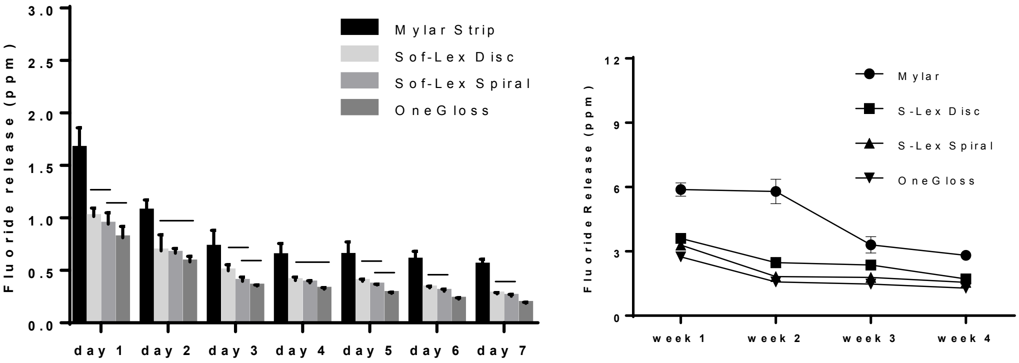

**Figure 5**. Mean fluoride release (ppm) of Beautifil Bulk.

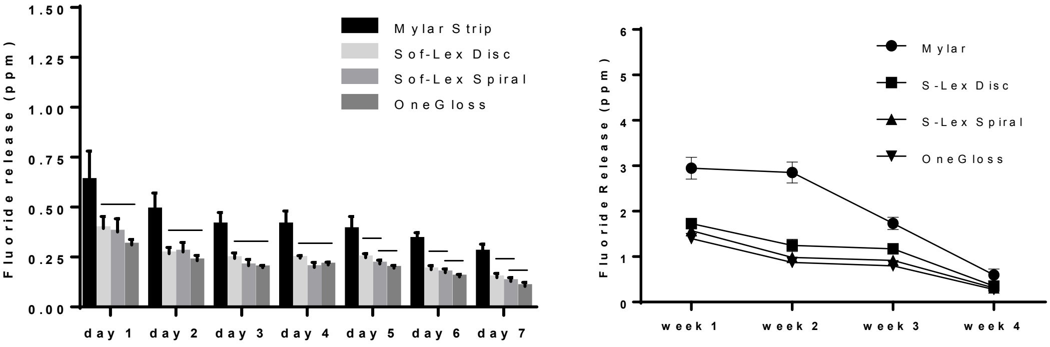

**Figure 6**. Mean fluoride release (ppm) of Filtek Ultimate.

**Table 4**. Surface roughness (Ra) values of the test materials (µm ± SD).

| | Mylar Band | S-Lex Discs | S-Lex Diamond | One Gloss |
|---|---|---|---|---|
| **Fuji IX GP** | 0.131 ± 0.011$^{aA}$ | 0.386 ± 0.048$^{aB}$ | 0.438 ± 0.045$^{ac}$ | 0.476 ± 0.047$^{ac}$ |
| **Fuji II LC** | 0.066 ± 0.012$^{bA}$ | 0.201 ± 0.021$^{bB}$ | 0.218 ± 0.024$^{bB}$ | 0.267 ± 0,017$^{bc}$ |
| **Dyract XP** | 0,04 ± 0,005$^{cdA}$ | 0,175 ± 0,034$^{bB}$ | 0,158 ± 0,013$^{cdB}$ | 0,206 ± 0,018$^{cc}$ |
| **Beautifil II** | 0,029 ± 0,004$^{eA}$ | 0,121 ± 0,013$^{cB}$ | 0,125 ± 0,010$^{eB}$ | 0,152 ± 0,006$^{dc}$ |
| **Beauti Bulk** | 0,034 ± 0,007$^{edA}$ | 0,125 ± 0,010$^{cB}$ | 0,141 ± 0,004$^{edc}$ | 0,166 ± 0,010$^{dD}$ |
| **F. Ultimate** | 0,025 ± 0,003$^{eA}$ | 0,080 ± 0,006$^{dB}$ | 0,082 ± 0,008$^{fB}$ | 0,153 ± 0.028$^{dc}$ |

*Different superscript (lowercase for each column and uppercase for each row) imply significant difference according to one-way ANOVA and Tukey HSD ($p<0.05$).

## DISCUSSION

Finishing and polishing procedures are essential for the clinical success of restorations (17). Therefore, in our study, we aimed to evaluate the effects of different polishing systems on the fluoride release during the first week and weekly for 1 month. Surface roughness values were also analyzed. Considering the results of the study, both hypotheses of the authors were rejected. Both the restorative materials and the polishing systems used have affected surface roughness and fluoride release. In addition, a strong positive correlation between surface roughness and fluoride release was observed ($r=0,745$; $p<0.05$).

The GICs show a rapid fluoride release as a result of the acid base reaction. This rapid fluoride release so called “burst effect” occurs on the surface of the material and markedly reduced after the first week. In many studies, particularly after the second week, the rate of fluoride release is slowed so that there is virtually no difference in fluoride elution between days (8,24-26). This “burst effect” phenomenon and subsequent threshold of constant fluoride release level was also consistent with the present study.

The fluoride elution of resin-modified GICs depends not only on the source of fluoride, but also on the type of resin monomer used (25,27,28). The setting of these materials initially begins with light-activated polymerization and is followed by the acid base reaction in association with the sorption of water. Fuji II LC contains HEMA hydrophilic monomer, which could increase the water sorption to allow fluoride ion diffusion (29). Similarly, in our study, the more fluoride release was observed in the traditional GIC material in the first week, whereas in the following weeks a greater amount of fluoride was released in the resin-modified GIC material. This can be also attributed to the acid base reaction and hydrogel thickening resulting from the water absorption indicated in another study (30).

The amount of fluoride released from the compomer material is less than that of both conventional and resin-modified GIC in accordance with previous studies (29-31). Dyract XP produced a higher amount of fluoride release than resin-based composites. According to manufacturer information, Dyract XP contains strontium fluoride. In some studies, it was demonstrated that glass fillers and ytterbium trifluoride exhibited a superior fluoride release compared to strontium fluoride (28,31). The fluoride glass in the giomer has almost no glass-ionomer matrix, and there is a significant lack of acid base reaction since it has been pre-reacted. In contrast, the acid base reaction in compomers occurs due to the water absorption. The authors thought that this variation may be the reason for the difference of fluoride release between these two materials. Mousavinasab and

Meyers (25), similar to our study, reported that the fluoride release of giomers was lesser than the compomer material. However, in another study, the investigators did not find a significant difference between the fluoride release of giomers and compomers (24).

The smoothest surfaces are generally obtained by using the Mylar strip (24,32,33). Even if it has been applied successfully, it may be necessary to carry out finishing procedures in order to remove excess material or to obtain a good occlusal relationship. For this reason, in order to provide a standardization, the surface of the materials was polished using a 1200-grit silicon carbide paper with a polishing machine prior to polishing application to simulate finishing procedures(24,34). In our study, the smoothest surfaces were obtained in the Mylar strip group in accordance with many studies (24,32,33). The surface roughness of the materials was significantly increased with the application of polishing system ($p<0.05$). The surface roughness of the resin-based materials is significantly lower than the GIC material ($p<0.05$). On the other hand, there was no significant difference between the surface roughness of Beautifil II, Beautifil-Bulk and Filtek Ultimate materials in Mylar strip and OneGloss subgroups ($p> 0.05$). In giomers, Sof-Lex Discs and Diamond systems were showed no statistically significant difference in surface roughness ($p> 0.05$), while Filtek Ultimate showed a better polishability ($p<0.05$).

As a result of the studies, a surface roughness of 0.2 μm is accepted as a threshold value for bacterial retention (35). In our study, the resin-based materials remained below this threshold. Only Dyract XP produced a surface roughness of 0.206 μm when polished with OneGloss. On the other hand, GIC-based materials have a surface roughness above 0.2 μm with all polishing systems. The lowest surface roughness in GIC-based materials was obtained with the Sof-Lex Discs system. The flexible structure and the planar motion of these discs may be associated with low surface roughness values.

The effect of finishing and polishing systems on the fluoride release of restoration materials has so far been the subject of several studies (23,24,36). One of these studies stated that removal of the surface of the materials by air-abrasion increases the elution of fluoride. In the same study, this increase was related to the increase in surface roughness (23). In another study, it was found that different finishing and polishing systems were effective on fluoride release but no correlation was found (24). A positive correlation between surface roughness and fluoride release of materials was found in the present study. A significant increase was observed in the fluoride release of the material with the increase in surface roughness of GIC-based materials. The alterations in the surface of the material together with the polishing may have facilitated the penetration of the water required for the acid base reaction. On the other hand, polishing of resin-based materials (excluding compomer) reduced the fluoride release in accordance with the previous study (24).

Based on the results, it may be concluded that the polishing significantly increases the amount of fluoride release of restorative materials depending on the material type. Furthermore, a positive correlation was found between the surface roughness and fluoride release of the materials tested. However, it is important to remember that the correlation is not causality when interpreting the correlation. There may or may not be a causal link between the two related variables. Also, if there is a correlation, this may be indirect. The smoothest surfaces were obtained with Sof-Lex discs. Sof-Lex Diamond system may be used especially for surfaces where the discs are difficult to use due to the anatomy of the teeth in the posterior region. GIC-based materials have more fluoride release than resin-based materials when polished.

## CONFLICT OF INTEREST

The authors have no conflict of interest relevant to this article.

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