

Original Article:

Compressive Strength, Fluoride Release and Recharge of Giomer

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Abstract:

Current restorative materials with high fluoride release generally have lower mechanical properties. Therefore they may not be as durable clinically as lower fluoride release materials, particularly in load bearing areas. The aim of the present study is to explore the fluoride release and recharging ability as well as its compressive strength of the newly developed material called Giomer. The name Giomer is a hybrid of the words Glass Ionomer and Composite. Giomer contain a revolutionary PRG (Pre Reacted Glass) filler technology. They have properties of both conventional Glass Ionomer (fluoride release and recharge) and resin Composite (excellent esthetics, easy polishability and biocompatibility). **MATERIALS & METHODS:** Seven disk specimens of Giomer, Compomer and Glass Ionomer restorative materials were prepared for measurement of fluoride release and recharge using Ion Chromatography (IC) anion analyzer machine. Another seven disk specimens of Giomer, Compomer and Composite restorative materials were prepared for measurement of compressive strength using Universal Testing Machine (UTM). **RESULTS:** The value of compressive strength of Giomer is greater than that of Composite and Compomer but the fluoride release capability of Giomer becomes low in comparison to Glass Ionomer but not significant in comparison to compomer. **CONCLUSIONS:** Giomer have high compressive strength (271 Mpa) and an initial fluoride (1.41 ppm) release. It also exhibit fluoride recharge capabilities. So, Giomer to be a better restorative material other than any fluoride releasing materials.

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Introduction:

New materials are being introduced to address the need for restoring both carious and non carious (caused by a combination of abrasion, erosion and abfraction) lesions. In an era when more and more patients are retaining their natural dentition, the need for this restoration is increasing. The ideal material should be adhesive, tooth-colored and abrasion resistant¹.

During the last decade, resin-based composite materials have been used widely to restore posterior teeth^{2,3,4}. Occlusal and proximal wear have been identified as possible limitations of resin-based composite materials in posterior restorations. Other areas of concern include marginal leakage, discolouration, polymerization shrinkage and post operative sensitivity⁵. Some of these clinical characteristics have improved over time as the adhesive technology has advanced and additional features, such as fluorides, have been added to the materials^{6,7,8}.

One feature that has enhanced resin-based restorative materials is fluoride release; several fluoride containing materials have been developed, such as resin-modified glass-ionomer, compomer and fluoride-containing resin based composite⁹. A new class of fluoride releasing resin materials with "Pre Reacted Glass" or PRG has been introduced with claims of good color matching and decreased micro leakage and increased fluoride release as compared with other resin materials.

The addition of Pre Reacted Glass (PRG) filler to the resin matrix has been the latest trend for the giomer materials. The PRG filler allows the material to release fluoride and be recharged with fluoride which is an excellent characteristic for long term fluoride release¹⁰.

In continuing quest for improved glass-ionomer like restoratives, manufacturers have developed and introduced a new class of materials called "Giomer". These are a relatively new type of restorative material. The name Giomer is a hybrid of the words "glass-ionomer" and "composite". Their manufacturer's claimed they have properties of both glass-ionomers (fluoride release, fluoride recharge) and resin composites (excellent esthetics, easy polishability and biocompatibility)

Giomer is a tooth colored restorative material that uses a resin base and PRG technology. The

PRG filler is made by reacting the acid-reactive glass containing the fluoride with polyalkenoic acid in water before being incorporated into the resin materials. This technology is different from that used in compomers, in which dehydrated polyalkenoic acid is part of the resin matrix, and the reaction between the glass and the acid does not occur until water is taken up by the restorative material. Two types of PRG filler are available: Surface reacted PRG filler (S-PRG) technology and Fully reacted PRG filler (F-PRG) technology. The restorative material used in this study is composed of the S-PRG filler. Properties of S-PRG technologies includes, maintaining the property of multifunctional glass, high level of radio opacity, fluoride release and recharge, biocompatible, long term clinical study, resistance to wear of posterior tooth and anti plaque effect¹¹.

Fluoride is well documented as an anti cariogenic agent. Fluoride-releasing restorative materials may be able to reduce the recurrent caries at the restoration margins^{12, 13, 14, 15, 16}. Recurrent caries is the most frequent cause for the failure of dental restorations^{7,17}. A variety of mechanisms are involved in the anticariogenic effects of fluoride, including the formation of fluoroapatite that has lower solubility than the original carbonated apatite, the enhancement of remineralization, interference of ionic bonding during pellicle and plaque formation, and the inhibition of microbial growth and metabolism^{18, 19}. Fluoride released from restorative materials can inhibit caries through all these mechanisms although it seems likely that the enhancement of remineralization is the major mechanism by which fluoride released from restorative materials is effective¹⁸. These anticariogenic and bacteriostatic effects vary widely among different materials and largely depend upon the amount of fluoride the material releases.

As Giomer is a new product having cross linked polymer matrices, the compressive strength and toughness of the material also seems to be higher than the gel network formed by acid-base reaction in glass-ionomers. Generally, it is found that the materials having high fluoride release property has low compressive strength. However, from clinical demand a material that has high fluoride release and recharge ability as

well as high compressive strength is considered a better restorative material. As Giomer is resin based PRG fillers, its compressive strength is expected to be comparable to any other resin-based material.

The present study is therefore intended to explore its compressive strength along with its fluoride release and recharge in comparison to glass-ionomer, compomer and resin composites.

Test Specimens

Seven disk samples of glass-ionomer, compomer and giomer restorative materials were prepared for measurement of fluoride release and recharge and another seven disk samples of compomer, giomer and composite restorative materials were prepared for measurement of compressive strength. The nature and composition of these

Materials & Methods

materials are given in Table 1. Composite (Quixfil, Caulk, Dentsply, Germany) contained a fluoro-alumino-silicate glass, which has no glass-ionomer hydrogel component, in a resin matrix. Compomer (Dyrect Extra, Dentsply DeTrey, Germany) contained a strontium-fluoro-silicate glass in which a limited glass-ionomer hydrogel formation will be possible through a delayed acid base reaction. Giomer (Beautiful II, Shofu Inc. Japan) in which the fluoridated glass filler will be fully reacted with acid to form an extensive glass-ionomer hydrogel layer before blending with a resin. Glass-Ionomer (Fiji IX, GC America) product which contained a calcium-fluoro-alumino silicate glass filler will be fully reacted with acid to form an extensive glass-ionomer hydrogel layer.

Table 1: Materials used in this study

Type	Manufacturer	Resin or Liquid composition	Filler composition	Materials Trade name
Glass-Ionomer	GC, America	PAA, H ₂ O	Ca-Al-F silicate Glass	Fuji IX
Compomer	Dentsply, Caulk, Germany	TCB, UDMA	Sr-F-Silicate Glass, SrF ₂	Dyrect Extra
Giomer	Shofu, Japan	Bis-GMA & TEGDMA	SPR Fluoroboro-Al-Silicate Glass filler, Nano Filler, Multi Fluoroboro-Al-Silicate glass filler	Beautiful II
Composite	Dentsply, Caulk, Germany	Urethane-modified Bis GMA	Ba-Al-F-Silicate glass, TiO ₂ , Fumed SiO ₂	Quixfil

Sample Preparation for Fluoride Release and Recharge:

Seven disk specimens of each material were prepared for measurement of fluoride release. Freshly mixed materials were applied in cylindrical Teflon moulds (10 mm diameter and 4 mm height) according to manufacturer's directions. The materials were infused into the Teflon moulds and press between two microscope glass slides. Except for self cure glass-ionomer, all specimens were light cured through the glass slides for 40 sec top and bottom surfaces. Then the specimens were taken out from the mould and again light curing for 40 sec on each cylindrical side surface. The self

curing specimens were allowed to set in the mould between the glass slides. A visible light unit (Selector, Taiwan) was used throughout the study. After polymerization, all specimens were ground with a dry 800 grit silicon carbide paper and their diameter and thickness were measured. The dimensions were used to calculate precisely the cross section area and surface area.

Fluoride Release Experiment Procedure:

The test specimens were immersed and stored in individual plastic containers with 5 ml distilled or deionised water at 37⁰c for 24hr. After that, each specimen were removed from its container and placed in a new container with 5 ml distilled or deionised water. This was repeated every day

for 6 days. The fluoride concentration of the storage water were measured by using an ISE (ION Selective Electrode) and IC (Ion Chromatography) and the result of fluoride release was calculated as the amount of fluoride release per unit surface area of specimen ($\mu\text{g}/\text{cm}^2$) in Parts Per Million (PPM) or mg/lit.

Fluoride Recharge and Rerelease Experiment Procedure:

Following the determination of initial fluoride release, specimens were stored in distilled or deionised water (5 ml), which was charged daily, until 13 days. On the days 6 specimens will be soaked for a period of 1 hr in an aqueous Sodium Fluoride solution (250 PPM F). After this recharging, specimens were rinsed with copious amounts of distilled or deionised water, shake dry and were returned to a new container with 5 ml distilled or deionised water. The daily fluoride release for 1 day before recharging and 3 days after recharging and at 13 days was determined using both ISE (ION Selective Electrode) and IC (Ion Chromatography). The amount of fluoride release per unit surface area of specimen ($\mu\text{g}/\text{cm}^2$) in PPM was calculated at each time and the amount of fluoride recharge was indicated by the difference of fluoride release during the 24 hr period before and after recharging.

Sample Preparation for Compressive Strength Experiment:

For compressive strength measurement, a Teflon mould was constructed, 4mm in diameter and 6 mm in depth. The assembled mould was filled with materials, any excessive materials were squeezed out and two microscope glass slides were placed over both ends of the mould. All specimens were light cured through the glass slides for 40 sec top and bottom surfaces. Then the specimens were taken out from the mould and again light curing for 40 sec on each cylindrical side surface. A visible light unit (Selector, Taiwan) was used throughout the

study. After polymerization, all specimens were removed from the moulds and then stored for 24 hrs at 37°C in dry condition. The specimens were ground with a dry 800 grit silicon carbide paper and their diameter and thickness was measured.

Compressive Strength Experiment Procedure:

After measurement of all the surfaces of the samples, the specimens were placed into a compressive strength tester (Testometric AX, Universal Testing Machine) and were loaded (Cross-head speed 1.0 mm/min) to the fracture of the sample. The compressive strength for each specimen was determined from Eq.

$$CS = \frac{P}{\pi \times r^2}$$

Where CS is Compressive Strength in MPa, P is the load at fracture and r is the radius of the specimen.

Study Parameters:

The parameters of the study were the fluoride release and recharge in respect of days. The amount of fluoride release during the initial 6 days, after recharging with 250 ppm fluoride, then re-release of fluoride in 7th day and following 13 days. The compressive strength of resin based restorative materials at cross head speed 1.0 mm/min was also the parameter of the study.

Statistical Analysis:

Data were processed and analyzed with the help of computer software SPSS (Statistical Package for Social Science) version 11.5. The test statistics used to analyze the data were ANOVA and data were presented as mean \pm SD (Standard Deviation). The level of significance was set at 0.05 and p-value less than 0.05 was considered significant. The significant data were testing for multiple comparisons by Bonferroni multiple comparison tests.

Results:

Results of this study are shown in suitable tables and graphs. Important observations and results are described below:

For Compressive Strength:**Table-2.** Compressive strength of giomer, compomer and composite

Material	n	Range	Compressive strength (MPA)	
			Mean \pm SD	<i>P</i> value
Giomer	7	246.113-305.752	271.356 \pm 19.653	>0.05 ^{ns}
Compomer	7	151.943-327.488	203.444 \pm 59.345	
Composite	7	146.265-302.234	238.598 \pm 57.338	

ANOVA, ns = Not significant

Table-2 shows the highest mean compressive strength was found in giomer and lowest mean compressive strength was found in compomer

The mean difference in compressive strength between giomer and compomer, giomer and composite, compomer and composite was statistically not significant ($P > 0.05$)

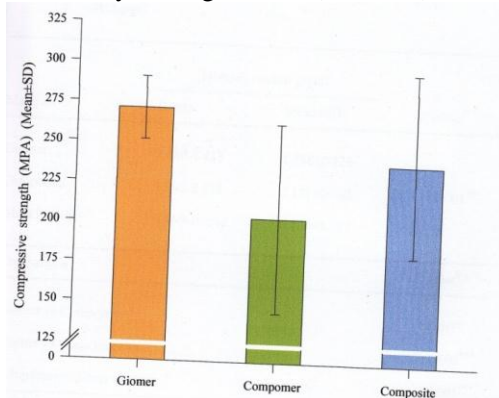


Fig. 1. Compressive strength of giomer, compomer and composite.

Fluoride Release (Before Recharge)On Day One:**Table-3.** Fluoride release by giomer, compomer and glass ionomer on day 1 (before recharge)

Material	n	Range	Fluoride release (ppm)	
			Mean \pm SD	<i>P</i> value ^a
Giomer	7	1.080-1.413	1.288 \pm 0.126	<0.001 ^{***}
Compomer	7	1.997-2.439	2.111 \pm 0.162	
Glass ionomer	7	6.460-10.562	8.538 \pm 1.282	
Comparison			<i>P</i> value ^b	
Giomer vs Compomer			>0.10 ^{ns}	
Giomer vs Glass ionomer			<0.001 ^{***}	
Compomer vs Glass ionomer			<0.001 ^{***}	

^aANOVA, ^bBonferroni multiple comparison

ns = Not significant, *** = Significant

Table-3 shows the highest mean fluoride release in glass-ionomer and lowest mean fluoride release in giomer.

There was no significant difference in fluoride release between giomer and compomer ($P > 0.10$)

The mean difference in fluoride release on day one between giomer and glass-ionomer ($P < 0.001$) and compomer and glass-ionomer ($P < 0.001$) were statistically significant.

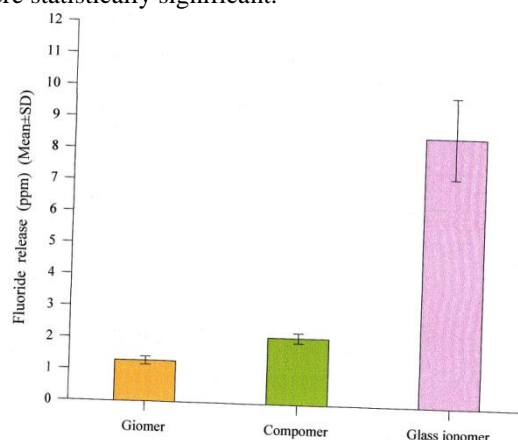


Fig.2. Fluoride release by giomer, compomer and glass ionomer on day 1 (before recharge)

On Day Six (Before Recharge)

Table-4. Fluoride release by giomer, compomer and glass ionomer on day 6 (before recharge)

Material	n	Fluoride release (ppm)		<i>P value</i> ^a
		Range	Mean±SD	
Giomer	7	0.164-0.373	0.246±0.064	<0.001 ^{***}
Compomer	7	0.419-0.522	0.473±0.037	
Glass ionomer	7	0.950-1.174	1.040±0.073	
<i>P value</i> ^b				Comparison
Giomer vs Compomer			<0.001 ^{***}	
Giomer vs Glass ionomer			<0.001 ^{***}	
Compomer vs Glass ionomer			<0.001 ^{***}	

^aANOVA, ^bBonferroni multiple comparison

*** = Significant

On day six before recharging Table.4. shows the highest mean fluoride release was found in glass-ionomer and lowest mean fluoride release was found in giomer.

The mean difference in fluoride release on day six between giomer and glass-ionomer; giomer and compomer; compomer and glass-ionomer were statistically significant ($P < 0.001$)

Fluoride Release (After Recharge)

On Day 7

Table-5. Fluoride release by giomer, compomer and glass ionomer on day 7 (after recharge)

Material	n	Fluoride release (ppm)		<i>P value</i> ^a
		Range	Mean±SD	
Giomer	7	0.190-0.418	0.313±0.073	<0.001 ^{***}
Compomer	7	0.434-0.581	0.497±0.044	
Glass ionomer	7	1.279-1.508	1.371±0.082	

Comparison	<i>P value</i> ^b
Giomer vs Compomer	<0.001 ^{***}
Giomer vs Glass ionomer	<0.001 ^{***}
Compomer vs Glass ionomer	<0.001 ^{***}

^aANOVA, ^bBonferroni multiple comparison
 *** = Significant

On day seven after fluoride recharge the highest mean fluoride release was found in glass-ionomer and lowest mean fluoride release was found in giomer.

The mean difference of fluoride release (after fluoride recharge) on day seven between giomer and glass-ionomer; giomer and compomer; compomer and glass-ionomer were statistically significant (P<0.001).

On Day Thirteen (After Recharge)

Table-6. Fluoride release by giomer, compomer and glass ionomer on day 13 (after recharge)

Material	n	Fluoride release (ppm)		<i>P value</i> ^a
		Range	Mean±SD	
Giomer	7	0.089-0.193	0.147±0.032	<0.001 ^{***}
Compomer	7	0.353-0.426	0.393±0.026	
Glass ionomer	7	0.826-0.988	0.904±0.060	

Comparison	<i>P value</i> ^b
Giomer vs Compomer	<0.001 ^{***}
Giomer vs Glass ionomer	<0.001 ^{***}
Compomer vs Glass ionomer	<0.001 ^{***}

^aANOVA, ^bBonferroni multiple comparison
 *** = Significant

On day thirteen the highest mean fluoride release was found in glass-ionomer and lowest mean fluoride release was found in giomer.

The mean difference of fluoride release on day thirteen between giomer and glass-ionomer; giomer and compomer; compomer and glass-ionomer were statistically significant (P<0.001).

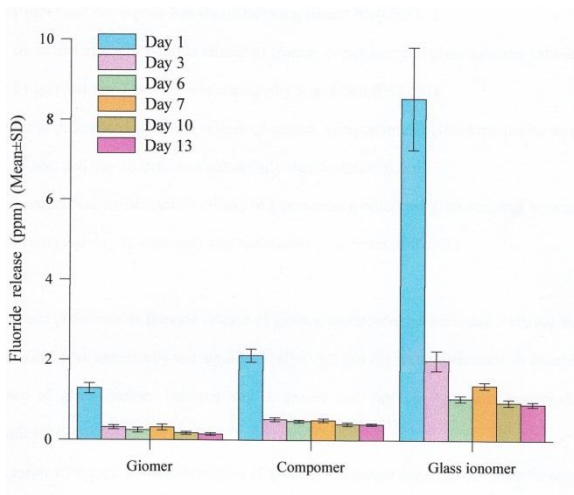


Fig.3. Fluoride release by giomer, compomer and glass ionomer (before and after recharge)

Discussion:

The mean \pm SD compressive strength of giomer was 271.356 ± 19.653 MPa. Regarding compressive strength of giomer comparison could not be shown due to lack of data from other study.

Xu et al. (2003) found the mean compressive strength of compomer 262 MPa. This finding is higher than the present study finding. The difference may be due to small sample size, defect in storage of sample or due to manufacturers problem²⁰.

The value of compressive strength of giomer is greater than that of compomer and composite.

The content of fluoride in restorative materials should, however, be as high as possible without adverse effects on physic mechanical properties and the release also should be as great as possible without undue degradation of the filling.

Forsten (1998) stated that an initial fluoride burst effect is desirable, as it will reduce the viability of bacteria that may have been left in the inner carious dentin and induce enamel/dentin remineralisation. High level of fluoride release on the day 1st day may be caused by the initial superficial rinsing effect, while the constant fluoride release during the following days occurs because of fluoride ability to diffuse through cement pores²¹.

Xu et al. (2003) observed that glass-ionomer have an initially high ($40 \mu\text{g}/\text{cm}^2/\text{day}$ or 8 ppm) fluoride release but it declines rapidly after the first 3 days. After that, the fluoride release sustains at a lower level for a long time. It also exhibit higher fluoride recharge capabilities. This result supports the present result²⁰.

Xu et al. (2003) also observed that compomer initially release a low level of fluoride (less than $10 \mu\text{g}/\text{cm}^2/\text{day}$ or 2 ppm) and sustain this release at the similar level for a long time. It is important to consider that different methodology used in the studies, including specimen size, media used to measure fluoride release and uptake, quantity of media used to measure fluoride and different method to measure fluoride release are responsible for the high numerical differences found among studies²⁰.

According to Bell et al (2000), Creanor et al (1994), Attar and Turgut (2003), fluoride release during first 24 hour from glass-ionomer was

nearly 15ppm which is higher to the findings of the present study^{22, 23, 24}.

Attar and Onen (2002) stated that fluoride release of compomer during first day was 1 to 2.4 ppm which is quite similar with the present finding²⁴.

In the present study fluoride release of giomer during first day was 1.288 ppm which is quite similar with the findings from Itota et al. (2003)²⁵. Despite the fact that previous studies have not been consistent in demonstrating long term fluoride release from giomer restorative materials.

All the materials tested in this study could uptake fluoride by applied recharging agent i.e. 250 ppm fluoride solution.

In present study, after recharge (on day 7) re-release of fluoride from giomer and compomer were 0.313 ppm and 0.497 ppm but Itota et al found them 0.224 ppm and 0.112 ppm respectively.

Fluoride release increases substantially 1 day after recharge but declines rapidly to the base line level after 2 to 3 days. This indicates that only a superficial part of the sample has been recharged due to a short recharge time (1 hour). This finding is similar to that of the present study.

Mousavinasab S. M. And Meyers I. (2009) showed in his study that the amount of total and free fluoride release from giomer was higher than compomer and also showed that gomers and compomers do not have the initial fluoride burst effect associated with glass-ionomer. This findings coincides with the present study²⁶.

Finally, a low release of fluoride from dental materials may have clinical implications *in vivo*. Fluoride release from glass ionomer restorations increases the fluoride concentration in saliva and in adjacent hard dental tissues. Thus, continuous small amounts of fluoride surrounding the teeth decreases demineralization of the tooth tissues although, it is not proven by prospective clinical studies whether the incidence of secondary caries can be significantly reduced by the fluoride release of restorative materials²⁷. Dentin demineralization was inhibited in a clinically relevant percentage only at fluoride levels above 1 ppm²⁸. Near optimum fluoride effects can be achieved with quite low concentrations in a daily fluoride rinse²⁹. The effect of a very low amount

of continuous fluoride release from giomers and compomers on dental hard tissues is needed to be further studied.

Conclusions:

Conventional glass-ionomer seem to offer the best balance of fluoride release and recharge for the high caries risk patients although giomer restorative materials continue to develop and have increased fluoride release and mechanical

properties. Further investigations will be necessary according to fluoride release of giomer in different methodology. Materials that have high fluoride release, high recharge capability, excellent mechanical properties and bonding properties are highly desirable and will be the targets of future development and giomer to be a better restorative material other than any fluoride releasing restorative materials.

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