Original Article

Effect of Fluoride Recharge on the Microleakage of Fluoride-Releasing Restorative Materials: An *Ex Vivo* Confocal Laser Scanning Microscopy Study

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ABSTRACT

Context: Success or failure of a restoration depends on its ability to bond to the tooth structure, to reduce microleakage, and to inhibit secondary caries. Fluoride-releasing materials have the inherent potential to release fluoride and are also capable of recharging themselves with topical agents. **Aim:** The aim of this study was to compare and evaluate the effect of fluoride recharge on microleakage of different restorative materials. **Materials and Methods:** Eighty extracted teeth were collected and split mesiodistally into 160 specimens. Class V cavities were prepared on buccal and lingual surfaces. Specimens were divided into four groups of 40 each based on the restorative material. Group I: Glass ionomer; Group II: Resin composite; Group III: Giomer; and Group IV: Alkasite. The restored teeth were stored in artificial saliva. Each group was divided into four subgroups for fluoride recharge and subsequent confocal laser scanning microscopy (CLSM) examination: (A) no fluoride recharge and CLSM examination after 24 h, (B) no fluoride recharge and CLSM examination after 3 weeks, (C) fluoride recharge once at third week followed by CLSM examination at 6 weeks, and (D) fluoride recharge twice at third week and sixth week followed by CLSM examination at 9 weeks. **Statistical Analysis:** Kruskal–Wallis and Mann–Whitney *U* tests were performed to analyze the obtained data. **Results:** A significant difference in microleakage was noted among resin composite and other groups except Cention-N, whereas no significant difference was noted pre- and post-fluoride recharge. **Conclusion:** Increased microleakage was noted post-fluoride recharge, although statistically not significant.

KEYWORDS: *Acid phosphate fluoride, composite resin, confocal laser scanning microscopy, dental leakage, topical fluorides*

INTRODUCTION

Background

Since the onset of their introduction, fluoride-releasing dental materials have become a part of dentist's armamentarium. They provide considerable fluoride release during function and help tooth resist caries along the cavosurface margins.

Glass ionomers were developed from aluminosilicate glass with calcium and fluoride flux. This material requires an acidic polymer to induce an acid–base reaction.[1] The ability to bond to the tooth structure, fluoride release, similar coefficient of thermal expansion to the tooth structure, less microleakage, and good retention are advantages of glass ionomers

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to name a few.[2] Major drawbacks include strength and opacity.

In recent times, resin composite has gained popularity because of its excellent esthetic and other favorable characteristics. However, the downside includes lack of fluoride-releasing capabilities and polymerization shrinkage, which creates stress on the network and its bonding system leading to secondary caries and marginal leakage.[3,4] Unlike conventional composites, Tetric N-Ceram is capable of both fluoride release and recharge. Dispersion of leachable glass/soluble fluoride salts (ytterbium trifluoride) into the polymer matrix allows for a water-soluble diffusion of fluoride from the composite resins.[1]

Giomers are dental restoratives containing prereacted glass ionomer (PRG) filler particles within a resin matrix. PRG filler is formed by an acid–base reaction between fluoride-containing glass particles and polyalkanoic acid in the presence of water before integration into the resin. Beautifil II uses S-PRG (surface PRG) where only the surface of the glass filler is attacked by polyacid and the core remains.[5] Owing to its properties of strength, wear resistance, radio-opacity such as composite and fluoride release, rechargeability such as ionomers, and giomer restoratives are proclaimed as true hybridization of glass ionomer and resin composites.[6]

De novo, another improvement was made in fluoride-releasing materials called alkasites. Like compomer or ormocer, these materials are essentially a subgroup of the composite class. Cention-N, an alkasite material, was mainly introduced as tooth-colored alternatives to amalgams with the ability to release fluoride. These materials use the alkaline filler capable of releasing acid-neutralizing ions.[7]

Rationale

Nevertheless, fluoride release from these materials may not last for long because they are depleted of fluoride. It was suggested that recharging them with fluoride ions could help sustain long-term release.

Fluoride toothpaste, fluoride mouth rinses, and other topical fluoride gels are different viable options for fluoride recharging. However, no distinct difference in caries prevention was noted among the methods.[8] Gels have the main advantage of stability and can stay in area of treatment for longer time without evaporation to achieve their effect.[9] Sodium fluoride (NaF), stannous fluoride (SnF_2), and acid phosphate are different viable options for topical applications of fluorides. Although SnF_2 has been shown to have positive effects both in terms of plaque formation, tooth stains, and gingival inflammation, it is not widely used as a fluoride recharge option.[10] Professional application of topical fluoride using 1.23% acidulated phosphate fluoride (APF) gel is more commonly used as it is more convenient and requires less chairside time.[11] APF gel is a mixture of NaF, hydrofluoric acid, and phosphoric acid with a pH range between 3.2 and 3.5.[12] Moreover, APF gel is considered a potent agent in releasing fluoride as compared to NaF 1% and SnF_2 4% gel.[11]

Microleakage may be defined as the clinically undetectable passage of bacteria, fluids, molecules, or ions between a cavity wall and the restorative materials.[2] The loss of marginal adaptation manifested as microleakage is a prime cause of secondary caries, postoperative sensitivity and staining, and/or loss of restoration, thus making it a topic of utmost importance and its assessment is the need of the hour.[13] Assessment of microleakage is usually performed by dye penetration tests.

Taking into account the importance of marginal adaptation for long-term success of restoration and fluoride recharge for long-term anticaries effect, this study was conducted to evaluate the inter-relationship between fluoride recharge and microleakage among four different test materials. This is a pioneer study taking into account these two factors.

Aim

The aim of this *in vitro* study was to compare and evaluate the effect of APF gel on microleakage of glass ionomer cement, resin composite, giomer, and alkasites at the tooth-restoration interface when restored in Class V cavities.

The null hypothesis tested was that (1) topical application of APF gel does not have any significant effect on microleakage of tested restorative materials and (2) there is no difference in microleakage among the test materials.

MATERIALS AND METHODS

The materials used are shown in Table 1.

SAMPLE COLLECTION AND PREPARATION

Eighty freshly extracted human maxillary and mandibular molars with normal crown morphology and intact buccal and palatal surfaces were included [Figure 1]. Teeth with any noticeable defects, caries, crazing, fractures, abnormal morphology, attrition, abrasion, occlusal wear facets, root canal treated or restored teeth, and third molars were excluded from the study.

Table 1: Materials used, their composition, manufacturer details, and usage instructions

Material	Composition	Manufacturer	Lot no./ batch no.	Manufacturer instructions
GC Fuji II	Powder Calcium fluoro aluminosilicate glass Liquid Polyacrylic acid	GC, Tokyo Japan	1608031	P/L ratio: 1 scoop of powder to 1 drop of liquid. Cavity is conditioned using GC cavity conditioner. Mixed cement is carried into the prepared cavity using placement instrument. Once set varnish is applied.
Cention-N	Powder Calcium fluoro-aluminosilicate glass, barium glass, calcium-barium-alumino fluoro-silicate glass, iso-fillers, ytterbium trifluoride, initiators, and pigments. Liquid dimethacrylate UDMA, DCP, PEG 400, initiators, stabilizers, and additives.	Ivoclar Vivadent,	W00300	P/L ratio: 1 scoop of powder to 1 drop of liquid Mixed material is applied to the prepared cavity, adapted and condensed it and remove excess material In addition, light cured for 40 s
Beautifil II	Bis GMA, TEGDMA, and S-PRG filler based on fluoroboroaluminosilicate glass, polymerization initiator, pigments, and others.	Shofu, Japan	061661	Available in syringe form Can be filled in increments upto 2mm thick Application of dentin adhesive followed by placement of material and light cured for 10 s
Tetric N ceram	Dimethacrylates (19%–21% weight). Inorganic fillers (75%–77% weight or 53%–55% volume) Fillers—barium glass, prepolymer, ytterbium trifluoride, and mixed oxide. Additives, catalysts, stabilizers, and pigments are additional contents (<1.0% weight).	Ivoclar Vivadent, Liechtenstein	U27917	Available in syringes and can be filled in bulk increments up to 4 mm. Acid etching of the prepared surface followed by application of tetric N bond and light cured. Place the required amount of composite using a plastic instrument. The material is light cured for 20 s

The teeth were cleaned off the debris and stored in saline at room temperature (36 ± 1°C). The teeth were sectioned longitudinally in a mesiodistal direction to produce 160 samples.

The samples were randomly divided into four groups of 40 each.

Group I—glass ionomer cement (Fuji II)

Group II—resin composite (Tetric N-Ceram)

Group III—giomer (Beautifil II)

Group IV—alkasite (Cention-N)

Preparation of class V cavities

Class V cavities measuring 4 mm wide × 2 mm high × 3 mm deep were prepared with no retentive features incorporated into cavity design. All cavosurface margins were placed in the enamel with 90° margin configuration and without bevels. No. 245 bur with high-speed air rotor handpiece with water coolant was used to prepare the cavities and bur was changed every five preparations. Cavities were standardized using a customized template and a graduated probe to further measure the depth.

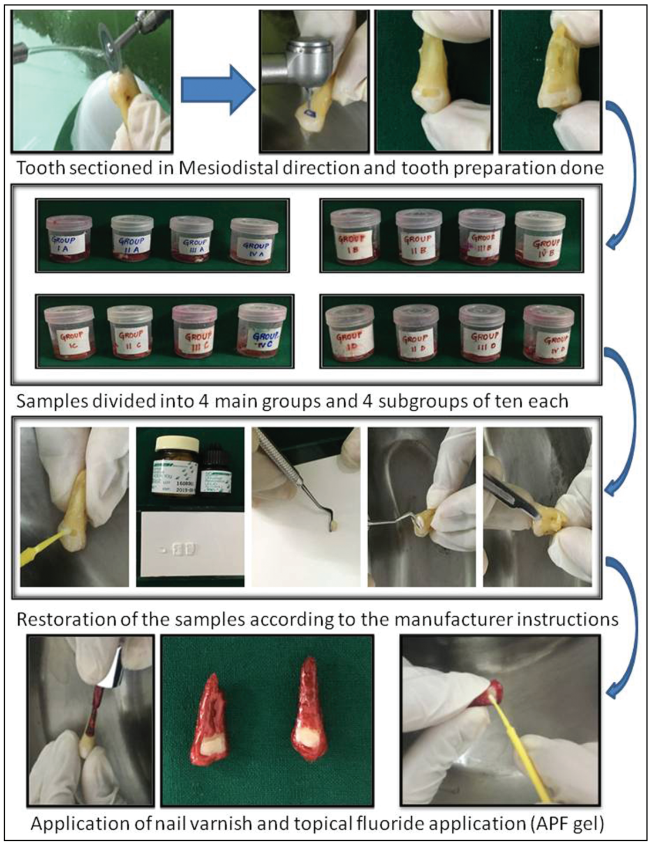

Figure 1: Sample preparation

RESTORATION OF CAVITIES

The preparations were restored in all groups with respective materials in accordance with the manufacturer's instructions [Table 1]. The restorations were then finished and polished using soflex discs (3M ESPE Dental, USA). The restored teeth were then stored in artificial saliva at room temperature (36 ± 1°C) and relative humidity (70%). Artificial saliva was replaced every 24 h.

FORMULATION OF ARTIFICIAL SALIVA

Artificial saliva was prepared according to the formulation suggested by Ionta *et al.*,[14] The composition includes 0.381 g NaCl, 0.213 g $CaCl_2.2H_2O$, 1.114 g KCl, 0.738 g KH_2PO4, and 2.2 g mucin in 1000-mL distilled water and pH 7.

FLUORIDE RECHARGE

In this *in vitro* study, fluoride recharge was performed at two time intervals and microleakage was evaluated at four time periods for each group [Figure 2].

CONFOCAL LASER SCANNING MICROSCOPY EVALUATION AND MICROLEAKAGE TESTING

The restored teeth were then subjected to 500 thermocycles at 5° and 55°C with a dwelling time of 1 min at each temperature. Ensuing thermocycling the specimens were prepared for immersion in dye

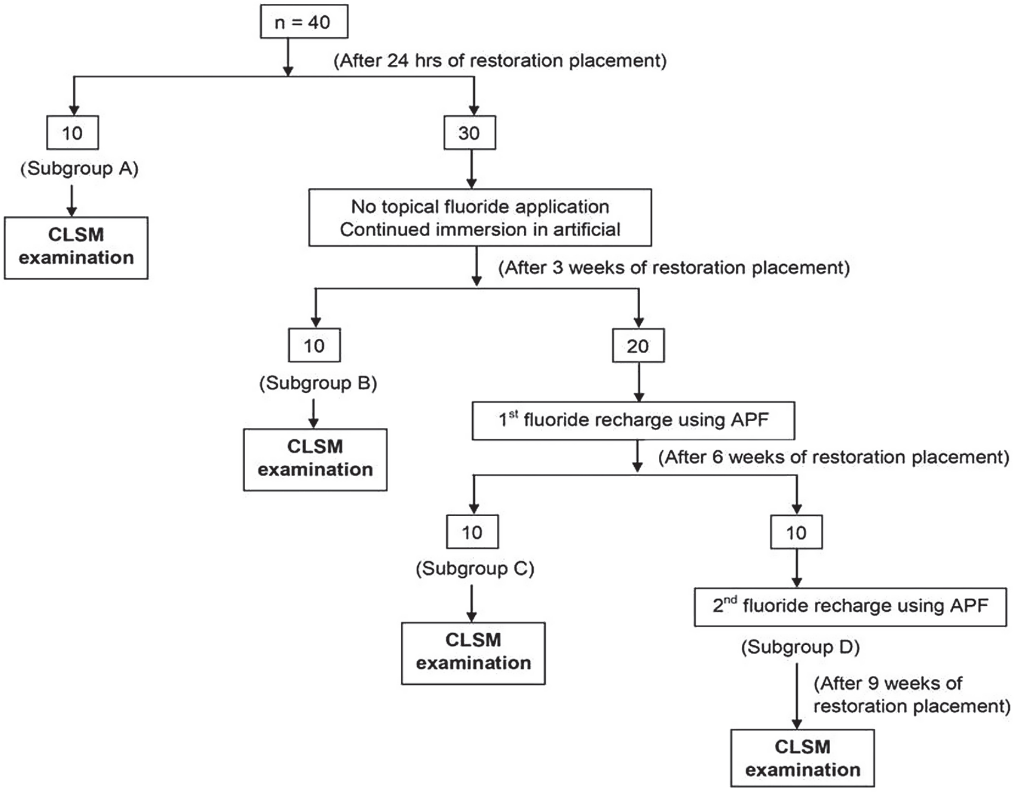

Figure 2: Flowchart of the study design

solution by application of two coats of nail varnish on all surfaces except for restoration and a 1–2 mm zone adjacent to its margins.

The teeth were then immersed in 0.5% Rhodamine B dye for 10 h. The radicular portions of the teeth were then separated leaving the coronal portions intact. The coronal portions were washed and mounted on acrylic blocks. The acrylic blocks were divided into two halves by sectioning longitudinally in a buccolingual direction. Each specimen was observed under confocal laser scanning microscopy (CLSM) to evaluate microleakage.

The extent of microleakage was noted according to the following criteria:[2]

1. 0—no marginal leakage.
2. 1—penetration to the enamel or cementum aspect of the preparation wall.
3. 2—penetration into the dentin aspect of the preparation wall, but not including the pulpal floor.
4. 3—penetration including the pulpal floor of the preparation.

The microleakage was examined using confocal microscopy in fluorescent mode [Figures 3–6].

Statistical analysis

Scores were recorded using the above criteria. The data were recorded and analyzed using the Statistical Package for the Social Sciences (SPSS) software program, version 22.0. The data were statistically analyzed using the Kruskal–Wallis test. Pairwise comparison among experimental groups was performed using Mann–Whitney *U* test. A value of $P < 0.05$ was considered statistically significant.

Results

This *in vitro* study revealed no statistically significant effect of topical fluoride application on microleakage [Table 2].

Intergroup comparison of four restorative materials for microleakage showed significant differences both before and after topical fluoride application [Table 3].

When experimental materials were compared, at all periods Group II (resin composite) showed less microleakage [Table 4].

In Subgroup A, statistically significant differences were noted between Groups I and II ($P = 0.039$), Groups II and III ($P = 0.015$), and Groups III and IV ($P = 0.044$). No statistically significant difference was noted between Groups I and III ($P = 0.692$), Groups I and IV ($P = 0.103$), and Groups II and IV ($P = 0.491$).

In Subgroup B, statistically significant differences were observed among Groups I and II ($P = 0.025$), Groups II and III ($P = 0.009$), and Groups III and IV ($P = 0.026$). No statistically significant difference was observed between Groups I and III ($P = 0.647$), Groups I and IV ($P = 0.064$), and Groups III and IV ($P = 0.687$).

In Subgroup C, statistically significant differences were observed between Groups I and II ($P = 0.006$), Groups I and IV ($P = 0.015$), Groups II and III ($P = 0.003$), and Groups II and IV ($P = 0.007$). No statistically significant difference was noted between Groups I and III ($P = 0.872$), and Groups II and IV ($P = 0.932$).

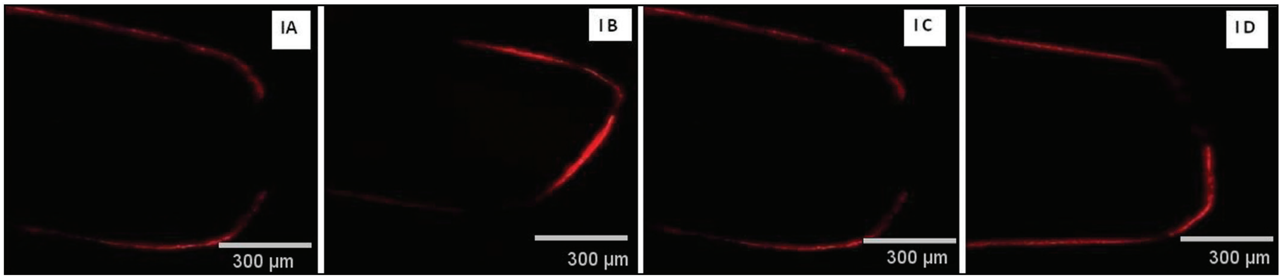

Figure 3: Representative confocal images of Group I

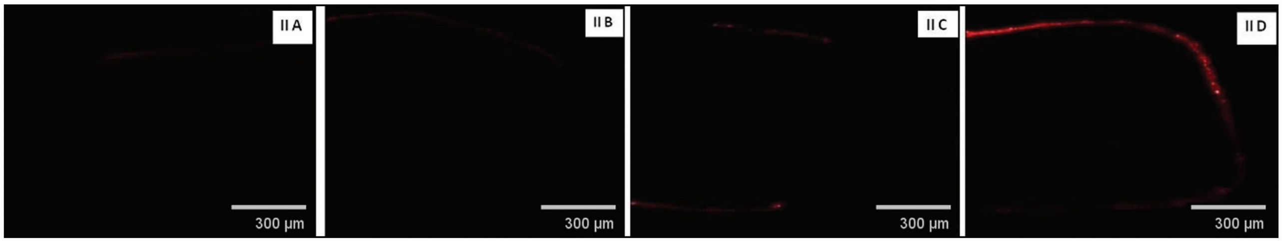

Figure 4: Representative confocal images of Group II

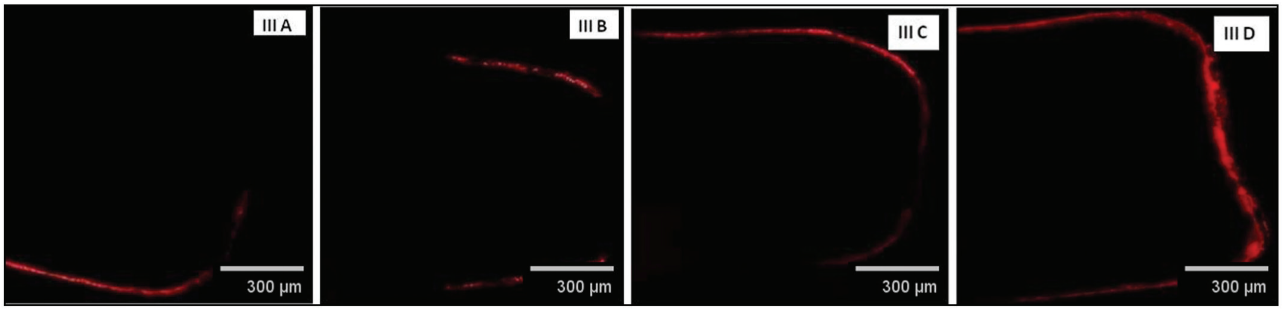

Figure 5: Representative confocal images of Group III

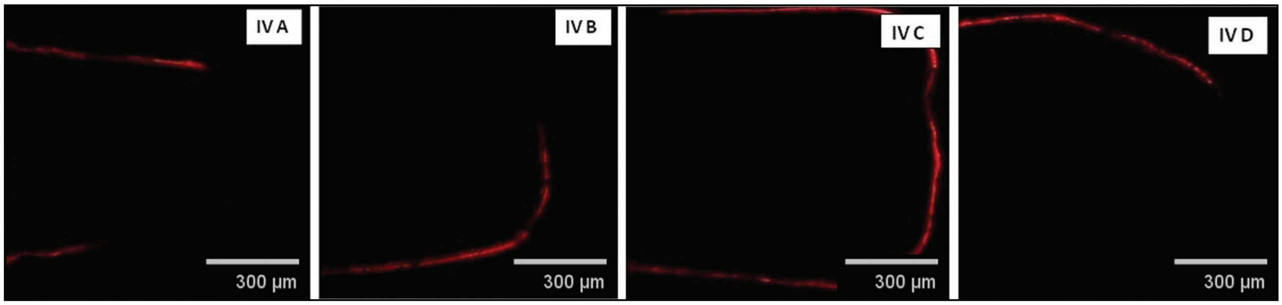

Figure 6: Representative confocal images of Group IV

In Subgroup D, statistically significant differences were observed among Groups I and IV ($P = 0.050$), Groups II and III ($P = 0.050$), and Groups III and IV ($P = 0.029$). No statistically significant difference was observed between Groups I and II ($P = 0.093$), Groups I and III, and Groups II ($P = 0.874$) and IV ($P = 0.903$).

Figures 3 and 5 show fluorescence between restoration and tooth surface in Group I and Group III, respectively, which indicates poor adaptation of the restorative material and gap formation. Figure 6 shows microleakage between restoration and tooth surface in Group IV with good adaptation of the material. Figure 4 shows practically no microleakage between restoration and tooth surface in Group II, which indicates well adaptation of the restorative material.

DISCUSSION

In vitro assessment of microleakage is a measure by which the clinical performance of a material can be predicted. This study was based on the premise that fluoride recharge did not have any effect on the sealing ability of the tested restorative materials. In an attempt to mimic the clinical scenario, microleakage in this study was assessed after being subjected to thermal fluctuation.

According to Alani and Toh,[15] no outstanding tool is currently available to detect microleakage around dental restorations. Despite its limitations, the dye penetration method using 0.5% Rhodamine-B was selected for this study because of its small particle size, better penetration, water-solubility, diffusability, and hard tissue nonreactivity.[16,17] CLSM was used in this study to evaluate the dye penetration as it is the least intrusive and destructive method of studying the interface between the restorative material and tooth structure. It eliminates sectioning and dehydration of specimens and polishing artifacts that exaggerate dye penetration.[2]

Fluoride-releasing restorative materials show a phenomenon of high initial fluoride release soon after placement of a restoration (“initial burst”). In time, fluoride levels gradually diminished over 3 weeks to a low-level, long-term release.[18] To simulate this clinical behavior of fluoride-releasing materials, fluoride recharge in this study was performed at 3 weeks intervals each, that is, third week and sixth week of initial placement of the restoration.

Fluoride recharge in this study did not have any significant effect on the microleakage of the test specimens. However, the number of specimens with greater microleakage scores increased post-fluoride application with all the test materials. A possible explanation could be the APF gel used in this study. APF gel contains hydrofluoric acid and phosphoric acid. These acids can etch glass particles and attack the inorganic matrix even at lower temperatures.[11]

Gladys *et al.*[19] and Yadav *et al.*[20] suggested that microleakage can be expected with all the dental materials available to date. Comparably, almost all the tested materials used in this study showed some extent

Table 2: Groupwise comparison of microleakage before and after fluoride recharge

Microleakage	Group IA		Group IB		Group IC		Group ID		Total	
	N	%	*n*	%	*N*	%	*n*	%	*n*	%
Score 0	2	20.0	1	10.0	1	10.0	1	10.0	5	12.5
Score 1	3	30.0	2	20.0	1	10.0	2	20.0	8	20.0
Score 2	4	40.0	5	50.0	5	50.0	4	40.0	18	45.0
Score 3	1	10.0	2	20.0	3	30.0	3	30.0	9	22.5
Total	10	100.0	10	100.0	10	100.0	10	100.0	40	100.0
Comparison by	$H = 2.465$									
Kruskal–Wallis test	$P = 0.482$									
Microleakage	**Group IA**		**Group IB**		**Group IC**		**Group ID**		**Total**	
	N	%	*n*	%	*N*	%	*n*	%	*n*	%
Score 0	7	70.0	6	60.0	6	60.0	5	50.0	24	60.0
Score 1	1	10.0	2	20.0	2	20.0	2	20.0	7	17.5
Score 2	2	20.0	1	10.0	2	20.0	1	10.0	6	15.0
Score 3	0	0.0	1	10.0	0	0.0	2	20.0	3	7.5
Total	10	100.0	10	100.0	10	100.0	10	100.0	40	100.0
Comparison by	$H = 1.058$									
Kruskal–Wallis test	$P = 0.787$									
Microleakage	**Group IA**		**Group IB**		**Group IC**		**Group ID**		**Total**	
	N	%	*n*	%	*N*	%	*n*	%	*n*	%
Score 0	1	10.0	0	0.0	0	0.0	0	0.0	1	2.5
Score 1	4	40.0	3	30.0	3	30.0	4	40.0	14	35.0
Score 2	3	30.0	4	40.0	3	30.0	2	20.0	12	30.0
Score 3	2	20.0	3	30.0	4	40.0	4	40.0	13	32.5
Total	10	100.0	10	100.0	10	100.0	10	100.0	40	100.0
Comparison by	$H = 1.619$									
Kruskal–Wallis test	$P = 0.655$									
Microleakage	**Group IA**		**Group IB**		**Group IC**		**Group ID**		**Total**	
	N	%	*n*	%	*N*	%	*n*	%	*n*	%
Score 0	5	50.0	5	50.0	6	60.0	5	50.0	21	52.5
Score 1	3	30.0	2	20.0	2	20.0	2	20.0	9	22.5
Score 2	2	20.0	2	20.0	1	10.0	2	20.0	7	17.5
Score 3	0	0.0	1	10.0	1	10.0	1	10.0	3	7.5
Total	10	100.0	10	100.0	10	100.0	10	100.0	40	100.0
Comparison by	$H = 0.326$									
Kruskal–Wallis test	$P = 0.955$									

$P < 0.05$ = significant

of microleakage. Upon examining the samples under CLSM, microleakage observed in various groups can be summarized as Group II (resin composite) < Group IV (alkasite) < Group I (GIC) < Group III (giomer).

Polymerization shrinkage,[10] thermal expansion coefficient, modulus of elasticity, hygroscopic expansion, bond strength, bond conditions, and factors associated with curing, flaw-related factors, occlusal stress, and thermocycling were considered most relevant factors for microleakage.[11] This makes reducing polymerization shrinkage one of the important issues.

Tetric N-Ceram is formulated with a special patented filler which is partially functionalized by silanes. These prepolymers act as a unique stress reliever and are responsible for the low shrinkage of materials. The stress reliever acts like a spring among the standard glass fillers with high elastic modulus and essentially holds onto the cavity walls along with matrix and adhesives eventually reducing the volumetric shrinkage and shrinkage stresses ensuring a tight marginal seal. In this study, resin composite showed significantly less microleakage as compared to other test materials except for alkasite at all periods and it is in agreement with the literature.[21]

Maximum leakage was observed for giomer, being attributed to the inherent nature of the material itself. Giomer mainly bonds to the tooth structure mechanically as it has no unreacted –COOH groups available to bond to the tooth structure.[6] S-PRG filler particles show a three-layer structure in which

Table 3: Groupwise comparison of four restorative materials with respect to microleakage

Microleakage	Group IA		Group IB		Group IC		Group ID		Total	
	N	%	*n*	%	*N*	%	*n*	%	*n*	%
Score 0	2	20.0	7	70.0	1	10.0	5	50.0	15	37.5
Score 1	3	30.0	1	10.0	4	40.0	3	30.0	11	27.5
Score 2	4	40.0	2	20.0	3	30.0	2	20.0	11	27.5
Score 3	1	10.0	0	0.0	2	20.0	0	0.0	3	7.5
Total	10	100.0	10	100.0	10	100.0	10	100.0	40	100.0
Comparison by Kruskal–Wallis test	$H = 8.839$ $P = 0.032$*									
Microleakage	**Group IA**		**Group IB**		**Group IC**		**Group ID**		**Total**	
	N	%	*n*	%	*N*	%	*n*	%	*n*	%
Score 0	1	10.0	6	60.0	0	0.0	5	50.0	12	30.0
Score 1	2	20.0	2	20.0	3	30.0	2	20.0	9	22.5
Score 2	5	50.0	1	10.0	4	40.0	2	20.0	12	30.0
Score 3	2	20.0	1	10.0	3	30.0	1	10.0	7	17.5
Total	10	100.0	10	100.0	10	100.0	10	100.0	40	100.0
Comparison by Kruskal–Wallis test	$H = 10.558$ $P = 0.014$*									
Microleakage	**Group IA**		**Group IB**		**Group IC**		**Group ID**		**Total**	
	N	%	*n*	%	*N*	%	*n*	%	*n*	%
Score 0	1	10.0	6	60.0	0	0.0	6	60.0	13	32.5
Score 1	1	10.0	2	20.0	3	30.0	2	20.0	8	20.0
Score 2	5	50.0	1	10.0	3	30.0	1	10.0	11	27.5
Score 3	3	30.0	1	10.0	4	40.0	1	10.0	8	20.0
Total	10	100.0	10	100.0	10	100.0	10	100.0	40	100.0
Comparison by Kruskal–Wallis test	$H = 15.180$ $P = 0.002$*									
Microleakage	**Group IA**		**Group IB**		**Group IC**		**Group ID**		**Total**	
	N	%	*n*	%	*N*	%	*n*	%	*n*	%
Score 0	1	10.0	5	50.0	0	0.0	5	50.0	11	27.5
Score 1	2	20.0	2	20.0	4	40.0	2	20.0	10	25.0
Score 2	4	40.0	1	10.0	2	20.0	2	20.0	9	22.5
Score 3	3	30.0	2	20.0	4	40.0	1	10.0	10	25.0
Total	10	100.0	10	100.0	10	100.0	10	100.0	40	100.0
Comparison by Kruskal–Wallis test	$H = 7.808$ $P = 0.050$*									

**P* Value is statistically significant

Table 4: Pairwise comparison of four restorative materials with respect to microleakage at different time periods

Comparison between	Subgroup A	Subgroup B	Subgroup C	Subgroup D
Group I vs. Group II	$P = 0.039$*	$P = 0.025$*	$P = 0.006$*	$P = 0.093$
Group I vs. Group III	$P = 0.692$	$P = 0.687$	$P = 0.872$	$P = 0.874$
Group I vs. Group IV	$P = 0.103$	$P = 0.064$	$P = 0.015$*	$P = 0.050$*
Group II vs. Group III	$P = 0.015$*	$P = 0.009$*	$P = 0.003$*	$P = 0.050$*
Group II vs. Group IV	$P = 0.491$	$P = 0.647$	$P = 0.932$	$P = 0.903$
Group III vs. Group IV	$P = 0.044$*	$P = 0.026$*	$P = 0.007$*	$P = 0.029$*

**P* Value is statistically significant

the glass core is enveloped by a stable glass-ionomer hydrogel.[22] It is supposed that the presence of a prereacted hydrogel is responsible for high levels of fluoride release and recharge. This property also increases the solubility of the material. Polymerization shrinkage and hygroscopic expansion, and inherent properties of the material also play an important role in marginal deterioration.[6]

No significant differences in microleakage were noted among the Tetric group and Cention-N. Cention-N is a dual-cure material and can be used as a full-volume replacement material. It is important to minimize shrinkage stresses for such material to be applied in bulk. Identical to Tetric N-Ceram, Cention-N contains a shrinkage stress reliever with a low modulus of elasticity diminishing the forces generated during shrinkage. Moreover, the organic:inorganic ratio and the composition of the monomer accounts for its low volumetric shrinkage.[21,23] Reduced polymerization shrinkage could appertain to improved marginal integrity and reduced shrinkage stress force over the restorative/on the adhesive bond.

The fluoride release and chemical bonding nature of glass ionomers are well known. However, the cohesive strength of glass ionomer is lower than the adhesive strength.[13] A stereomicroscopic study conducted by Fuks *et al.*[24] showed Fuji II to have a granulated texture with many cracks and air voids. This porous nature of the material may enhance its potential for microleakage. Similar results were observed in a study conducted by Mali *et al.*[13] comparing glass ionomer, composite, and compomer. Glass ionomer cement showed more microleakage compared to composite and compomer.

Considering the microleakage pattern of glass ionomers in this study, a slight variation in microleakage was noted post fluoride recharge. A significant difference was noted post-fluoride application when compared to Cention-N. Although APF gel seems to be most effective at increasing fluoride release by restorative materials compared to 1% neutral fluoride gel, 0.001% calcium fluoride, and 4% SnF_2, it is found that APF gel creates superficial erosion on the outmost surface of the composite resin and glass ionomer cement.[23,25] Previous studies also observed that a 1.23%APF gel application for 4 min increased the surface roughness of conventional glass ionomer.[26-28] This should relate to the significant difference between the two materials after the application of APF gel in this study.

Arruda *et al.*[29] evaluated the effect of APF gel on the surface roughness of different composite resins and reported a significant difference in roughness after the application of 1.23% APF gel. However, this study did not report any difference in microleakage post-topical fluoride application. The absorption and re-release of fluoride might be partly determined by the permeability of the material. A complete permeable substance could absorb ions deep into its bulk, whereas a relatively permeable material can only absorb fluoride into its surface.[30] In the previous study, APF gel was applied immediately after restoration placement. Presuming the material to have high permeability immediately after placement of a restoration, the difference in time of APF application might have accounted for nonidentical results in this study. However, not enough literature is available to date regarding the effect of APF gel on giomers and alkasites and hence could not be related to in this study.

CONCLUSION

From the study, the following conclusions can be drawn:

1. Despite the insignificant difference observed in microleakage after topical application of APF gel, dentists are advised to be cautious when using APF gel as a fluoride recharge option.
2. Considering the microleakage, resin composites performed better than all other tested materials, whereas Cention-N, a new restorative alternative performed comparable to composite materials and can be used in contemporary practice.

LIMITATIONS

The following are the limitations of the study:

1. No mechanical cyclic loading was performed during the study to assess the effect of mechanical stresses on the restoration behavior.
2. Dye penetration in this study was not carried out under vacuum which could have resulted in more reliable results.

FUTURE SCOPE/CLINICAL SIGNIFICANCE

Within the limitations of this study, further research can be focused on the surface analysis of restorative material after fluoride recharge and the fluoride release profiles using different recharge protocols.

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CONFLICTS OF INTEREST

Not applicable.

AUTHORS CONTRIBUTIONS

Not applicable.

ETHICAL POLICY AND INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable.

PATIENT DECLARATION OF CONSENT

Not applicable.

DATA AVAILABILITY STATEMENT

The data set used in this study is available on request from corresponding author (e-mail: gavini.snigdha@gmail.com).

REFERENCES

1. Hicks J, Gracia-Godoy F, Donly K, Flaitz C. Fluoride releasing restorative materials and secondary caries. Dent Clin North Am 2002;46:246-76.
2. Bollu IP, Hari A, Thumu J, Velagula LD, Bolla N, Varri S, *et al*. Comparative evaluation of microleakage between nano-ionomer, giomer and resin modified glass ionomercement in class V cavities: CLSM study. J Clin Diagn Res 2016;10:ZC66-70.
3. Patel MU, Punia SK, Bhat S, Singh G, Bhargava R, Goyal P, *et al*. An *in vitro* evaluation of microleakage of posterior teeth restored with amalgam, composite and zirconomer: Stereomicroscopic study. J Clin Diagn Res 2015;9:ZC65-67.
4. Lo Giudice G, Cicciù M, Cervino G, Lizio A, Visco AM. Flowable resin and marginal gap on tooth third medial cavity involving enamel and radicular cementum: A SEM evaluation of two restoration techniques. Indian J Dent Res 2012;23:763-9.
5. Naoum S, Ellakwa A, Martin F, Swain M. Fluoride release, recharge and mechanical property stability of various fluoride-containing resin composites. Oper Dent 2011;36:422-32.
6. El Gezawi MF, Elsalawy RN. Sealing performance and wear resistance of new resinglass ionomer formulations in class V cavities. Egypt Dent J 2006;52:1217-30.
7. Mazumdar P, Das A, Das UK. Comparative evaluation of microleakage of three different direct restorative materials (silver amalgam, glass ionomer cement, Cention N), in class II restorations using stereomicroscope: An *in vitro* study. Indian J Dent Res 2019;30:277-81.
8. Øgaard B, Seppa L, Rolla G. Professional topical fluoride applications: Clinical efficacy and mechanism of action. Adv Dent Res 1994;8:190-201.
9. Fiorillo L, Romano GL. Gels in medicine and surgery: Current trends and future perspectives. Gels 2020;6:1-4.
10. Fiorillo L, Cervino G, Herford AS, Laino L, Ciccù M. Stannous fluoride effects on enamel: A systematic review. Biomimetics 2020: 5:1-22.
11. Basir L, Khataminia M, Babashahi E, Rohani A. The effect of acidulated phosphate fluoride (APF) on the microleakage of composite flow and fissure sealant restorations. J Res Med Dent Sci 2018;6:536-43.
12. Kula K, Thompson V, Kula T, Nelson S, Selvaggi R, Liao R. *In vitro* effect of topical fluorides on sealant materials. J Esthet Dent 1992;4:121-7.
13. Mali P, Deshpande S, Singh A. Microleakage of restorative materials: An *in vitro* study. J Indian Soc Pedod Prev Dent 2006;24:15-8.
14. Ionta FQ, Mendonça FL, de Oliveira GC, de Alencar CR, Honório HM, Magalhães AC, *et al*. *In vitro* assessment of artificial saliva formulations on initial enamel erosion remineralization. J Dent 2014;42:175-9.
15. Alani AH, Toh CG. Detection of microleakage around dental restorations: A review. Oper Dent 1997;22:173-85.
16. Wimonchit S, Timpawat S, Vongsavan N. A comparison of techniques for assessment of coronal dye leakage. J Endod 2002;28:1-4.
17. Going RE. Microleakage around dental restorations: A summarizing review. J Am Dent Assoc 1972;84:1349-57.
18. Cakir-Utsun D, Lawson NC, Burgess JO. Fluoride-releasing materials. In: Hilton TJ, editor. Summit's Fundamentals of Operative Dentistry: A Contemporary Approach. 4th ed. New Delhi: Quintessence Publishing; 2014. p. 380-96. (Indian Edition)
19. Gladys S, Van Meerbeek B, Lambrechts P, Vanherle G. Microleakage of adhesive restorative materials. Am J Dent 2001;14:170-6.
20. Yadav G, Rehani U, Rana V. A comparative evaluation of marginal leakage of different restorative materials in deciduous molars: An *in vitro* study. Int J Clin Pediatr Dent 2012;5:101-7.
21. Abrol A, Aggarwal N, Gupta P, Mallika, Kunjam, Abrol N. Comparative evaluation of microleakage around class II cavities restored with Zirconomer, Tetric N-Ceram, Cention-N and Glass Ionomer cement: An *in vitro* study. Int J Curr Res 2019;11:1641-44.
22. Najma Hajira NSW, Meena N. GIOMER: The intelligent particle (new generation glass ionomer cement). Int J Dent Oral Health 2015;2.
23. Soumita S, Das UK, Mitra A. Comparison of microleakage in class V cavity restored with flowable composite resin, glass ionomer cement and Cention N. Imp J Interdiscip Res 2017;3:180-3.
24. Fuks AB, Hirschfeld Z, Grajower R. Marginal adaptation of glass-ionomer cements. J Prosthet Dent 1983;49:356-60.
25. Botta AC, Mollica FB, Ribeiro CF, de Araujo MAM, Di Nicoló R, Balducci I. Influence of topical acidulated phosphate fluoride on surface roughness of human enamel and different restorative materials. Rev Odonto Ciênc 2010;25:83-7.
26. Ylp HK, Smales RJ. Fluoride release and uptake by aged resin-modified glass ionomers and a polyacid-modified resin composite. Int Dent J 1999;49:217-25.
27. Yeh ST, Wang HT, Liao HY, Su SL, Chang CC, Kao HC, *et al*. The roughness, microhardness, and surface analysis of nanocomposites after application of topical fluoride gels. Dent Mater 2011;27:187-96.
28. Gill NC, Pathak A. Comparative evaluation of the effect of topical fluorides on the microhardness of various restorative materials: An *in vitro* study. J Indian Soc Pedod Prev Dent 2010;28:193-9.
29. Arruda MM, Toppino MA, Barbosa GM, Costi HT, Silva CM, Nogueira Araújo JL. Effect of fluoride gels on the surface roughness of different composite resins. Open Dent J 2020;14:474-81.
30. Kumari PD, Khijmatgar S, Chowdhury A, Lynch E, Chowdhury CR. Factors influencing fluoride release in atraumatic restorative treatment (ART) materials: A review. J Oral Biol Craniofac Res 2019;9:315-20.