RESEARCH PAPER

Comparative Microleakage Analysis Of Flowable Composite And Flowable Glass Ionomer In Class I Restoration

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Abstract

Objective: To evaluate and compare microleakage in class I restorations using flowable glass ionomer cement (GIC) and flowable composite resins in permanent teeth.

Materials and Methods: A total of 85 non-carious, human premolars, extracted for orthodontic purposes received standardized class I cavities prepared by a single operator. Teeth were randomly assigned to four experimental groups: A(n=17) – Light curing flowable composite (3M, USA); B(n=17) – Flowable Glass ionomer cement (Kids-e-Dental); C(n=17) – Light curing flowable composite (GC Dental); D(n=17) – Light curing Nano-Hybrid flowable composite (SafeEndo); and one control group: E(n=17) – Unrestored cavity (negative control group). These restorations followed manufacturers' protocols. The samples underwent thermocycling (5 –55 °C), immersion in 2% methylene blue for 24 h, mesiodistal sectioning, and stereomicroscopic evaluation (24.5×) to assess the rate of microleakage. Data were analysed using the Kruxskal-Wallis test with Bonferroni post hoc correction ($p < 0.05$).

Results: Group D, (Light curing Nano-Hybrid flowable composite (SafeEndo)) (100%) exhibited the least microleakage, followed by Groups C (Light curing flowable composite (GC Dental)) (94.11%), Group A (Light curing flowable composite (3M, USA)) (64.7%), and Group B (Flowable Glass ionomer cement (Kids-e-Dental)) (17.64%) ($p < 0.001$).

Conclusion: Light curing flowable composite (GC Dental) and Light curing Nano-Hybrid flowable composite (SafeEndo) showed the best marginal sealing performance, likely due to its optimized resin matrix, advanced filler technology, and enhanced adaptation to cavity walls. Clinically, this may reduce secondary caries, postoperative sensitivity, and restoration failure, making it a reliable choice for pediatric restorative treatments where durability and integrity are critical.

Keywords: flowable hybrid composite, glass ionomer cements, methylene blue, microleakage

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Introduction

While restoring carious dentition, it is necessary to prepare the tooth structure minimally, remove affected tissue made of bacteria, and then use a restorative material to restore the tooth structure. The main goal of dental restoration is to protect the tooth from caries recurrence in the future while simultaneously restoring its cosmetic integrity and chewing function.[1] For survival in the mouth, the restorative material has to adhere to the tooth structure.[2] Microleakage was described by Kidd in 1976 as the transfer of microorganisms, fluids, chemicals, or ions from a hollow wall to a restorative material.[3] It leads to pulpal injury, discoloration of the tooth enamel, hypersensitivity, and the deterioration of restorative materials.[4] Therefore, one of the outcomes responsible

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for the success and duration of restoratives is the presence or absence of microleakage.

A restorative material should closely mimic the structure of natural tooth tissue, have excellent mechanical and cosmetic properties, and withstand the conditions found in the mouth for a prolonged period. Along with these considerations, the capacity to apply restoration materials to cavities with ease and speed is of utmost importance, particularly in pediatric dentistry. Despite its flaws, glass ionomer cements (GICs) are the go-to for pediatric dental restorations due to their chemical bonding with tooth enamel and ability to release fluoride. Many improvements have been made in GICs to improve physical characteristics as well as clinical performance of conventional GICs, including their wear resistance, aesthetic longevity, and potentially their marginal adaptation and sealing ability.[5] Although this technology has come a long way, especially with the advent of coated and high-viscosity varieties, researchers are yet to elucidate how well glass ions work in the long run and how much better they are at preventing microleakage than modern composite resins.[6] Conversely, flowable composite resins have become more popular as restorative materials due to their adaptability to cavity walls, ease of handling, and excellent aesthetics, especially in conservative preparations. The polymerization shrinkage is a major issue with composite resins because it stresses the tooth-restoration interface and can cause microleakage or marginal gap formation. This tendency significantly reduces the restoration's lifetime by contributing to postoperative sensitivity, marginal discoloration, and recurrent cavities.

Given the persistent challenge of microleakage across various restorative materials and the continuous evolution of their formulations, a direct comparison between established and novel material types is imperative. The development of advanced GICs and refinements in composite formulations warrant a re-evaluation of their performance regarding marginal integrity. Therefore, the objective of this *in vitro* study was to evaluate and compare the microleakage between three commercially available flowable composite restoratives and a contemporary flowable glass ionomer restorative to provide evidence-based insights into their clinical suitability for pediatric restorative procedures.

Materials and Methods

The present *in vitro* experimental study was carried out in the Department of Pediatric and Preventive Dentistry, Sathyabama Dental College and Hospital, Chennai, India. The ethical approval for the study was obtained from the Institutional Review Board of Sathyabama Dental College and Hospital (Ref. 529/IRB-IBSEC/SIST, December 10, 2024. This study was conducted over a period of approximately ten months, from the date of ethical approval to its completion.

Sample size estimation

The sample size was calculated by using OpenEpi software, with a confidence level of 95% and a power of 80. Based on inclusion and exclusion criteria 85 tooth were selected, with 17 in each group.

Sample size considered

A total of 85 human premolars extracted for therapeutic or orthodontic reasons were collected for this study for a span of six months from various clinics and clinicians. The inclusion criteria required that all teeth be sound, non-carious, non-fractured, and unrestored. Teeth with caries, developmental anomalies, hypoplastic defects, fractures, or existing restorations were excluded.

Sample preparation and storage

After sample collection, teeth were debrided of soft tissue and calculus using hand scalers and rinsed thoroughly under distilled water. All samples were then stored in distilled water at room temperature to prevent dehydration and preserve structural integrity. The storage medium was replaced at regular intervals to avoid bacterial contamination.

Cavity preparation

Standardized class I occlusal cavities were prepared on the occlusal surfaces, using a high-speed air-rotor handpiece with a cylindrical diamond bur (no. 245 bur, 0.8 mm diameter, and 3 mm length; Dentsply Sirona, York, PA, USA) under continuous water cooling. The cavity dimensions were standardized to 1 mm in width, 1 mm in length, and 1 mm in depth, measured with a Williams's periodontal probe. In order to minimize variability, a new bur was employed after every five preparations.

Grouping of samples

Samples were randomly assigned into five groups with n = 17 cavities each:

Group A – Filtek Supreme® flowable composite (3M, USA); Group B – Kids-e-Restore flowable GIC (India); Group C – G-Aenial Flo flowable composite (GC, Japan); Group D – ReCreate-LC Flow (SafeEndo®); and Group E- control group.

Protocol

Group A - Light curing flowable composite (3M, USA): The dentin was gently air dried for 15 s to keep it moist, after which a 15 s etching process using a 37% phosphoric acid gel (D-Tech etch, D-Tech, India) was rinsed with water for 30 s. After applying and air-thinning a universal adhesive (Scotchbond™ Universal Adhesive; 3M, St. Paul, MN, USA), it was light-cured for 20 s with an Elipar™ DeepCure-L LED curing unit (1200 mW/cm²) from 3M. The 3M supreme flowable composite was applied to the cavities in increments, cured for 20 s each, following the manufacturer's recommendations.

Group B - Flowable Glass ionomer cement (Kids-e-Dental): Cavity walls were conditioned with GC cavity conditioner (GC Corporation, Tokyo, Japan) for 20 s, rinsed thoroughly, and gently air-dried for 15 s without desiccation. Kids-e-Restore flowable GIC (Kids-e-Dental) was placed directly into the cavity as per manufacturer's instructions and light-cured for 20 s per increment.

Group C - Light curing flowable composite (GC Dental): The etching and bonding protocol described for Group 1 was followed. The cavities were restored with G-Aenial

Flo flowable composite (GC, Japan), placed incrementally and light-cured for 20 s per increment.

Group D - Light curing Nano-Hybrid flowable composite (SafeEndo): The total-etch adhesive protocol described for Group 1 was repeated. Cavities were restored with ReCreate-LC Flow (SafeEndo), applied incrementally, and light-cured for 20 s each.

Group E: Control group: Cavities were rinsed and air-dried but left unrestored, serving as the negative control.

Storage and thermocycling

For the first 24 h, all specimens were placed in distilled water and kept at 37°C (4). To replicate the changes in oral temperature, thermocycling was carried out for 1000 cycles at 5–55°C, with 30 s dwell time in each bath and 5 s transfer time.

Two coats of nail varnish were applied to every tooth's exterior after thermocycling, except the restoration and margins.

Microleakage evaluation

In accordance with the commonly used techniques for microleakage evaluation, the samples were submerged in a 2% methylene blue dye at room temperature for 24 h.[7-9] Samples were sectioned mesiodistally using a precision microtome (LeicaSP1600) and examined under a stereomicroscope at 24.5× (Leica EZ4D) magnification. Linear diffusion of dye from external margin of cement interface towards the pulpal wall was scored based on the following established criteria by Popoff et al.[10] which later was critically assessed by four investigators.

Score 0: No leakage observed.

- Score 1: Dye has penetrated up to one-third of the axial wall.
- Score 2: Dye has penetrated up to two-thirds of the axial wall.
- Score 3: Dye has penetrated across the entire axial wall.
- Score 4: Dye has penetrated to the pulpal wall.

Statistical analysis

A significance threshold of 95% was used in the statistical analyses conducted using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). Suitable non-parametric statistical tests have been used to analyse the microleakage scores obtained as ordinal data. All groups were given descriptive statistics, including median and interquartile range. Kruskal-Wallis H test was used to compare microleakage scores across the five groups. To compensate for multiple comparisons, post hoc analysis used Mann-Whitney U tests with Bonferroni correction.

Results

Table 1 shows the microleakage score distribution among the five groups. Almost every specimen showed no microleakage when sealed Group D, Light curing Nano-Hybrid flowable composite from SafeEndo (100%) or G-Aenial Flo GC, Japan (94.11%). While Group B, Flowable Glass ionomer cement from Kids-e-Dental (17.64%) displayed a broad spread of scores, Group A, Light curing flowable composite from 3M, USA demonstrated adequate performance (64.7%). The clinical linear diffusion of dye observed across all experimental groups is illustrated in Figures 1-5

The mean and standard deviation of microleakage scores are shown in Table 2. The control group exhibited the highest mean score (4.00 ± 0.00). Among the restorative materials, Group B (Flowable Glass ionomer cement (Kids-e-Dental)) showed the highest mean score, while Group D, (Light curing Nano-Hybrid flowable composite (SafeEndo)) (0.00 ± 0.00) showed the lowest mean value, stating no microleakage.

A Kruskal-Wallis H test revealed a statistically significant difference in microleakage among the five groups ($p < 0.05$). The mean ranks are presented in Table 3.

The results of the Bonferroni-adjusted post hoc testing showed that there was no statistically significant difference in the microleakage ratings of Group D, (Light curing Nano-Hybrid flowable composite (SafeEndo)), Groups C (Light curing flowable composite (GC Dental)), and Group A (Light curing flowable composite (3M, USA)(df > 0.05). Table 4 shows that compared to the Group B (Flowable Glass ionomer cement (Kids-e-Dental)) and the unrestored control group, all resin-based flowable composites had considerably decreased microleakage ($p < 0.05$).The interference from this is Nano-Hybrid flowable composite from safe endo and flowable composite from GC Dental shows reduced microleakage, when compared to the flowable glass ionomer cement from kids-e-Dental.

Discussion

The longevity of dental restorations is pivotal to the success of minimally invasive dentistry, as it hinges on the restorative material's ability to adhere effectively, adapt at margins, and resist degradation. Glass ionomer cement (GIC) chemically bonds to enamel and dentin, reducing the need for extensive cavity preparation. Its fluoride release offers anticariogenic benefits and enhances resistance to secondary caries, while its biocompatibility and thermal expansion compatibility with tooth structure support marginal integrity.[11] In contrast, composite resins lack intrinsic fluoride release, diminishing their anticariogenic potential. They depend on micromechanical bonding and are technique sensitive, with polymerization shrinkage contributing to marginal gaps and microleakage. Their placement demands strict moisture control, which may be challenging in Pediatric and subgingival cases, and often requires more extensive cavity preparation.[12] Hence, this research was planned to compare the microleakage among various commercially available flowable composite and the newer flowable glass ionomer cement Resin-modified glass ionomer cement (RMGIC) integrates the chemical adhesion and fluoride release of GIC with the mechanical strength, esthetics, and reduced moisture sensitivity of composite resins. Its hybrid composition makes it particularly suitable for pediatric and minimally invasive applications. This study evaluated the sealing efficacy of these materials under controlled laboratory conditions, contributing to the growing body of evidence on the clinical performance of flowable materials in pediatric restorative dentistry.[13]

Microleakage was assessed using the Popoff scoring system, recognized for its sensitivity and reproducibility. Dye penetration with methylene blue provided superior contrast and visualization under stereomicroscopy compared to alternative methods such as fluid filtration, bacterial leakage, or electrochemical analysis. This approach enabled standardized comparisons across materials, enhancing the reliability of results.

Flowable composite resins demonstrated superior sealing performance over flowable GICs, attributed to their reduced viscosity, thixotropic behaviour, and nano-filler-enhanced mechanical properties. In addition, our study's results show that newer formulations with nano sized fillers improve mechanical strength, wear resistance, and marginal gap development.[14] Their adaptability in layered restorations was further supported by Bhanwal et al.,[15] who reported significantly reduced microleakage when used as a base in Class II restorations. Conversely, GICs at flowable consistency, despite their fluoride release and chemical adhesion, exhibited higher moisture sensitivity, lower compressive strength, and greater solubility, compromising marginal integrity under thermocycling conditions.[16,17] The slower, moisture sensitive and acid base reaction may further exacerbate microleakage, reinforcing the clinical preference for flowable composites in scenarios demanding long-term durability and optimal sealing.

Although flowable GICs is more convenient in pediatric dentistry, sets faster, requires less strict moisture control than conventional GIC. This study showed higher microleakage among the flowable GIC than the commercially available flowable composites. This gives a clear idea of selecting ideal material.

Key limitations of this study is its reliance on in vitro data, which cannot fully emulate the complexities of the oral environment such as variations in salivary flow, thermal changes, and functional stresses from mastication. Consequently, long-term in vivo clinical trials and survival analysis are crucial to corroborate these laboratory findings and assess real time clinical performance. Future investigations should also explore the development of bioactive and hybrid restorative materials that integrate the mechanical robustness of composite resins with the fluoride-releasing and demineralizing properties of glass ionomer cements (GICs). Such innovations hold promise for delivering a more holistic and durable solution in pediatric restorative dentistry.

Conclusion

The optimized resin matrix, increased adaptation to cavity walls, and upgraded filler technology probably contribute to the material's superior performance by fostering a strong binding and minimizing micro gap formation. For pediatric restorative treatments, Light curing Nano-Hybrid flowable composite (SafeEndo) and Light curing flowable composite (GC Dental) are reliable options that prioritize repair durability and integrity.

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Table 1. Distribution of microleakage scores among the groups (n = 17 per group)

Groups	Score 0	Score 1	Score 2	Score 3	Score 4
Group A (Light curing flowable composite (3M, USA))	11 (64.7%)	6 (0)%	0 (0)%	0 (0)%	0 (0)%
Group B (Flowable Glass ionomer cement (Kids-e-Dental))	3 (17.64%)	1 (5.88%)	6 (35.29%)	5 (29.4%)	2 (11.7%)
Groups C (Light curing flowable composite (GC Dental))	16 (94.11%)	1 (5.88%)	0 (0)%	0 (0)%	0 (0)%
Group D, (Light curing Nano-Hybrid flowable composite (SafeEndo®))	17 (100%)	0 (0)%	0 (0)%	0 (0)%	0 (0)%
Unrestored control	0 (0)%	0 (0)%	0 (0)%	0 (0)%	17 (100%)

Table 2. Mean and standard deviation of microleakage scores

Group	N	Mean rank
Group A (Light curing flowable composite (3M, USA)	17	17.58
Group B (Flowable Glass ionomer cement (Kids-e-Dental))	17	48.8
Groups C (Light curing flowable composite (GC Dental))	17	3.76
Group D (Light curing Nano-Hybrid flowable composite (SafeEndo))	17	1
Unrestored control group	17	67

Table 3. Mean ranks of microleakage scores (Kruskal-Wallis H test)

Comparison	**Result**
3M vs. Kids-e-Dental	Significant ($p < 0.05$)
3M vs. GC	Significant ($p < 0.05$)
3M vs. SafeEndo	Not Significant ($p > 0.05$)
3M vs. Control	Significant ($p < 0.05$)
Kids-e-Dental vs. GC	Significant ($p < 0.05$)
Kids-e-Dental vs. SafeEndo	Significant ($p < 0.05$)
Kids-e-Dental vs. Control	Significant ($p < 0.05$)
GC vs. SafeEndo	Not Significant ($p > 0.05$)
GC vs. Control	Significant ($p < 0.05$)
SafeEndo vs. Control	Significant ($p < 0.05$)

Table 4. Pairwise comparisons using Bonferroni-adjusted post hoc tests

S. no.	Group	Mean ± standard deviation
1	Group A (Light curing flowable composite (3M, USA))	0.35 ± 0.49

2	Group B (Flowable Glass ionomer cement (Kids-e-Dental))	2.11 ± 1.26
3	Groups C (Light curing flowable composite (GC Dental))	0.05 ± 0.24
4	Group D, (Light curing Nano-Hybrid flowable composite (SafeEndo))	0 ± 0
5	Unrestored control group	4 ± 0

Figures

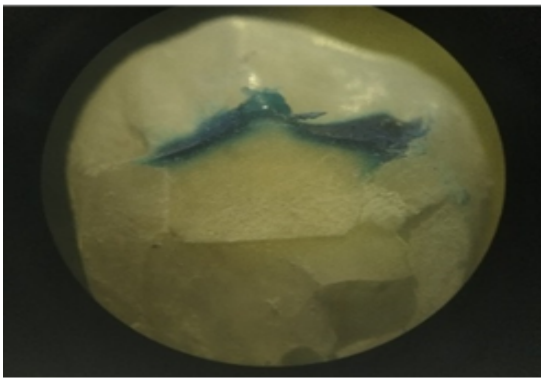

Figure1: Group A - Nanofilled flowable composite from 3M, USA, exhibiting marginal leakage under a stereomicroscope at 24.5×

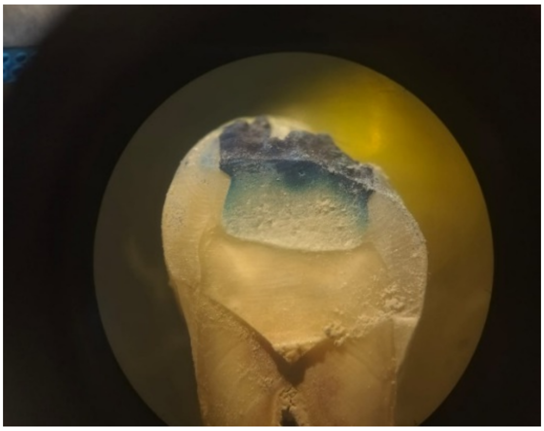

Figure 2: Group B - Flowable Glass ionomer cement from Kids-e-Dental, showing maximum microleakage up to the pulpal floor under a stereomicroscope at 24.5×

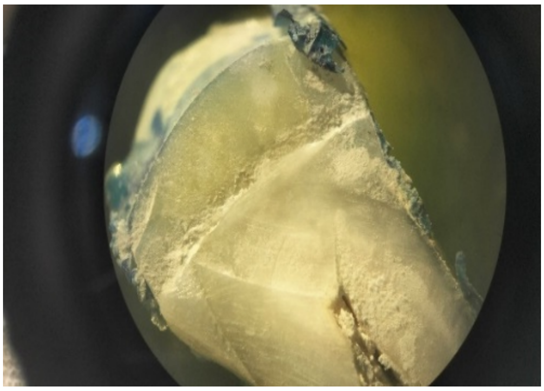

Figure 3: Groups C - High viscosity nanohybrid flowable composite from GC Dental, with considerably better sealing ability under a stereomicroscope at 24.5×

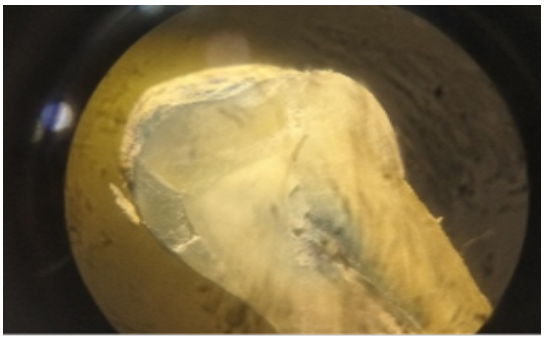

Figure 4: Group D- Nanohybrid flowable composite from SafeEndo, showing excellent sealing under a stereomicroscope at 24.5×

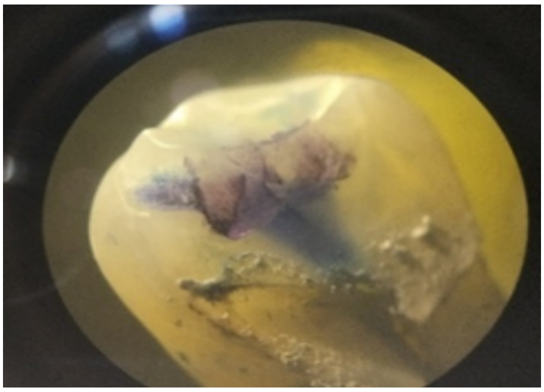

Figure 5: Group E- Unrestored control group, with complete dye penetration under a stereomicroscope at 24.5×