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ORIGINAL ARTICLE

Postoperative dentinal sensitivity following four restorative strategies in vital posterior teeth: a randomized controlled trial

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ABSTRACT

Objectives: To compare postoperative dentinal sensitivity following restoration of vital posterior teeth using four restorative strategies: total-etch resin composite, self-etch resin composite, high-strength glass ionomer cement (GIC), and bioactive resin restoration over a three-month follow-up period.

Methods: This single-center, parallel-group randomized controlled trial included 160 participants aged 18-40 years with Class I or Class II cavities in permanent molars. Participants were randomly allocated to four restorative groups (n=40 each). Postoperative dentinal sensitivity was assessed using a modified 100-mm Visual Analogue Scale at 24 hours, 48 hours, 7 days and 3 months. Between-group comparisons were performed using non-parametric tests, with stratified subgroup analyses according to gender and cavity class.

Results: Postoperative dentinal sensitivity decreased substantially over time in all restorative groups. At 24 hours, the self-etch resin composite demonstrated significantly lower sensitivity than the other restorative materials ($p<0.001$), whereas the high-strength GIC group exhibited the highest postoperative sensitivity ($p<0.001$). No significant difference was observed between the total-etch resin composite and bioactive resin groups ($p=1.000$). At three months, postoperative sensitivity was comparable among the total-etch, self-etch and bioactive resin groups, while the high-strength GIC group continued to demonstrate significantly greater sensitivity than the other restorative strategies ($p<0.001$). Male participants and Class I restorations showed significantly higher postoperative sensitivity within GIC group.

Conclusion: Self-etch resin composite was associated with the lowest immediate postoperative dentinal sensitivity, whereas high-strength GIC demonstrated significantly greater postoperative sensitivity that persisted at three months. Total-etch resin composite and bioactive resin restoration showed comparable short- and long-term clinical performance.

Clinical Trial Registration Number: NCT05882760

Keywords: Molar (MeSH); Resins, Synthetic (MeSH); Composite Resins (MeSH); Dental Cements (MeSH); Dental Adhesives (MeSH); Glass Ionomer Cements (MeSH); Postoperative Pain (MeSH); Randomized Controlled Trial (MeSH); Tooth Restoration (Non-MeSH); Dentin Sensitivity (MeSH); Bioactive Materials (MeSH).

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INTRODUCTION

Postoperative sensitivity (POS) is one of the most common complications following direct restorative procedures, adversely affecting patient satisfaction, treatment compliance, and the perceived quality of restorative care. Although POS associated with resin-based restorations is generally mild and self-limiting, its reported prevalence ranges from 11% to 30% following placement.[1,2] The etiology of POS is multifactorial. While the adhesive strategy alone may not be the principal determinant, several factors have been implicated, including restorative technique, material properties, microleakage, bonding failure, and polymerization shrinkage.[1,2] Clinically, patients typically experience thermal, osmotic, or occlusal sensitivity during the days or weeks following restoration. Persistent postoperative sensitivity not only compromises patient comfort but also challenges clinicians in selecting the most appropriate restorative material amid the rapid introduction of new adhesive systems and restorative materials.

The pathophysiology of postoperative sensitivity is primarily explained by the hydrodynamic theory, which proposes that external stimuli applied to exposed dentin induce rapid movement of fluid within patent dentinal tubules, activating A-delta mechanoreceptors at the pulpal interface and producing a transient pain response.[3] Although alternative mechanisms, including direct dentinal innervation and odontoblast transduction, have been proposed, the hydrodynamic theory remains the most widely accepted explanation and continues to guide restorative material selection and clinical practice. According to this theory, any restorative procedure that increases dentinal tubule permeability or compromises the dentin–restoration interface can promote dentinal fluid movement, resulting in postoperative sensitivity. During cavity preparation, removal of the smear layer exposes dentinal tubules, while frictional heat generated by rotary instrumentation

may transiently dehydrate dentin and alter tubular fluid dynamics.[4] These effects may be further exacerbated by the chemical and mechanical characteristics of restorative materials and bonding procedures, thereby increasing the risk of postoperative sensitivity.

Recent advances in restorative material science have led to the development of bioactive restorative materials designed to combine the esthetic and handling properties of resin composites with the ion-releasing and remineralizing capabilities of glass ionomer cements. Among these, Activa Bioactive Restorative (Pulpdent Corporation, USA) has emerged as a promising material, incorporating a dual-cure rubberized ionic resin matrix with reactive ionomer glass fillers capable of releasing calcium, phosphate, and fluoride ions at the dentin-pulp interface.[5] In addition, its rubberized resin matrix is intended to reduce polymerization shrinkage stress and improve resistance to occlusal loading. Short- to medium-term clinical studies have demonstrated favorable clinical performance, including reduced post-operative sensitivity and satisfactory restoration retention, compared with conventional resin composites.[6] However, evidence regarding its performance across different posterior cavity configurations and longer follow-up periods remains limited.[5,7,8]

Despite the extensive literature on postoperative sensitivity following posterior resin restorations, important knowledge gaps remain. Most comparative clinical trials have evaluated total-etch and self-etch adhesive systems alone, and systematic reviews have reported no significant difference in postoperative sensitivity between these adhesive strategies over extended follow-up periods.[1] Furthermore, the majority of published studies have focused on non-carious cervical lesions rather than Class I and Class II posterior restorations, with limited follow-up to assess persistent or late postoperative sensitivity. Compa-rative evidence evaluating high-strength glass ionomer cement and newer bioactive restorative materials alongside conventional adhesive resin composites is also scarce, particularly with respect to the influence of cavity class on postoperative sensitivity. Therefore, this randomized controlled trial was undertaken to compare postoperative dentinal sensitivity in vital posterior teeth restored using four restorative strategies: total-etch resin composite, self-etch resin composite, high-strength glass ionomer cement, and bioactive resin restorative, assessed at 24 hours, 48 hours, 7 days, and 3 months after restoration

METHODS

This single-center, parallel-group randomized controlled trial (RCT) was conducted at the Department of Operative Dentistry, Institute of Dentistry, Liaquat University of Medical and Health Sciences (LUMHS), Jamshoro, Pakistan, between May 2023 and December 2024. The trial was prospectively registered with ClinicalTrials.gov (NCT05882760). Ethical approval was obtained from the College of Physicians and Surgeons Pakistan (CPSP) [Reference No. CPSP/REU/DSG-2022-166-4159) and the LUMHS Ethical Research Committee (Reference No. LUMHS/REC-29; dated: March 17, 2023). The study was conducted in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines. Written informed consent was obtained from all participants before enrolment, with consent forms available in English, Urdu, and Sindhi. The participant recruitment and allocation process is illustrated in the CONSORT flow diagram (Figure 1).

Participants were recruited consecutively from patients attending the Department of Operative Dentistry and Endodontics, Liaquat University of Medical and Health Sciences (LUMHS), Jamshoro, using a non-probability consecutive sampling technique. Eligibility was determined by the principal investigator through clinical and radiographic examination before enrolment. Participants meeting the inclusion criteria and providing written informed consent were enrolled in the study. The detailed inclusion and exclusion criteria are presented in Table I.

Sample size was calculated using OpenEpi for comparison of two independent means, with a two-sided significance level of alpha=0.05 and statistical power of 80%. Reference postoperative sensitivity values were drawn from published RCT data: total-etch composite (mean±SD: 1.48±1.55), self-etch adhesive (0.25±0.63), and GIC (0.18±0.55) from Mushtaq U, et al.,[9] and bioactive resin (0.42±0.20) from Hirani RT, et al.[6] The largest pairwise contrast between total-etch composite and GIC yielded a conservative estimate of 36 participants per group. To maintain adequate power across all four pairwise comparisons and account for potential attrition, 40 participants were allocated to each group, producing a total enrolment of

Table I: Eligibility criteria for participant inclusion and exclusion

Inclusion Criteria	Exclusion Criteria
Adults of either sex, aged 18–40 years	Clinical or radiographic evidence of irreversible pulpitis
Class I or Class II cavities on maxillary or mandibular first or second molar	Cavities involving premolars or third molars
Vital tooth with confirmed occlusal contact with antagonist tooth	Pre-operative use of analgesics within 24 hours of treatment
Preoperative dentinal sensitivity ≥30 mm on the Visual Analogue Scale following cold stimulation	Known allergy or hypersensitivity to any study material
Ability to provide written informed consent	Parafunctional habits (e.g., bruxism or clenching) or significant malocclusion
Willingness to attend all scheduled follow-up visits	Multiple restorations required in the same quadrant during the same appointment

160 participants.

Eligible participants were assigned to one of four restoration groups using a computer-generated block randomization list prepared by an independent person not related to study. Block sizes were fixed at four to ensure balanced allocation throughout the enrolment period. Allocation was performed using sequentially numbered sealed opaque envelopes. In participants requiring multiple restorations, individual teeth were assigned to different groups in separate quadrants at separate appointments.

Participants were blinded to their allocated restoration material. Complete operator blinding was not feasible given the distinct handling properties of each material. Outcome assessors responsible for measuring VAS scores at the 7-day and 3-month clinical recall visits were blinded to group allocation.

Prior to the restorative appointment, each participant underwent; recording of demographic data, dental and medical history; clinical examination of the tooth to be restored; pre-operative bitewing radiography to assess carious lesion extent and proximity to the pulp; and baseline dentinal sensitivity measurement using the modified VAS with cold-air stimulation. Only participants with a Preoperative VAS score of ≥30 mm were eligible for inclusion.[10]

Pulpal vitality was confirmed in all enrolled teeth using a combination of the cold stimulation test (Endo Ice, Coltène/Whaledent) and electric pulp testing (EPT), with a normal pulpal response defined as sensitivity that subsided within 10 seconds of stimulus removal and absence of spontaneous pain.

All restorative procedures were performed by a single operator (principal investigator) to minimize inter-operator variability. Following local anesthesia and rubber dam isolation, standardized cavity preparations were performed using calibrated carbide burs in a high-speed handpiece with continuous water spray.

Caries was removed using a minimal intervention technique. To gain visible access, entrance to the lesion was initially gained using a round or fissure highspeed diamond bur under air-water coolant. Dentin caries at the pulpal floor and surrounding walls was then stained with a caries detector dye (Caries Detector, Kuraray Medical Inc, Okayama, Japan) for 10 seconds, rinsed off, then removed using slow-speed round steel burs and spoon excavators. The procedure was repeated two to three times until the dentin surface was stained pale pink and was relatively hard.

Cavity depth was standardized using calibrated burs with predetermined depth stops confirmed with a periodontal probe. Occlusal adjustments were performed with articulating paper, and finishing followed a uniform protocol for all composite groups.

Participants were randomly assigned to one of four restoration groups as follows. All light-curing procedures were performed using the CuringPen-X LED curing light (Eighteeth, Changzhou Sifary Medical Technology Co., Ltd., China), operating at an irradiance of 1000 mW/cm² in continuous mode, emission spectrum of 380–515 nm and tip diameter of 11 mm. Irradiance was verified using the device's integrated smart controller prior to each clinical session.

In group 1, both enamel and dentin surfaces were etched simultaneously for 15 seconds with 37.5% phosphoric acid gel. Tetric N Bond Universal (Ivoclar Vivadent) was applied and cured according to manufacturer guidelines. After that cavity was restored with Nano Hybrid Dental Composite Resin (Nexcomp, META BIOMED Co.) using incremental layering techniques.

In group 2, no separate phosphoric acid etching step was performed. Self-etch adhesive (Tetric N Bond Universal, Ivoclar Vivadent) was applied directly to the dentin surface using manufacturer instruction. Restoration was completed using the same incremental composite resin and curing protocol as Group 1.

In group 3, No adhesive was applied. GC Fuji IX powder and liquid were dispensed and mixed on a paper mixing pad according to the manufacturer instructions. Mixed material was introduced into the cavity using a plastic filling instrument and condensed. Initial finishing was performed at rubber dam removal; final finishing was completed exactly six minutes after the commencement of mixing. Patients were instructed to avoid occlusal loading on the restoration for one-hour post-placement.

In group 4, the cavity was etched with 37% phosphoric acid gel for 15 seconds, rinsed for 15 seconds, and blotted dry with a cotton pellet to produce a moist dentinal surface. Following etching. Active Bioactive Material was inserted according to manufacturer instructions. Finishing, polishing, and occlusal adjustment followed the same sequence as groups 1 and 2.

The primary outcome was postoperative dentinal sensitivity, measured using a modified Visual Analogue Scale (VAS). The modified VAS comprised a 100 mm horizontal line anchored at "No tooth sensitivity at all" and "Worst tooth sensitivity ever", supplemented by six facial expression pictograms with color coding to facilitate comprehension across literacy levels. Sensitivity was operationally defined as greater discomfort on the restored tooth than on an adjacent unrestored control tooth in response to a standardized stimulus. A VAS score exceeding 30 mm was considered clinically significant. Patients were also asked to record in a diary whether sensitivity was spontaneous or triggered by specific stimuli (chewing, cold air, heat, or cold water).

Postoperative sensitivity was assessed at 24 hours, 48 hours, 7 days, and 3 months post-restoration. For the 24-hour, 48-hour, and 7-day assessments, patients completed the modified VAS in a standardized take-home diary. Completed diaries were collected at the 7-day recall visit. Clinical recall assessments were conducted by blinded outcome assessors at 7 days and 3 months, with control measurements simultaneously recorded on adjacent unrestored enamel surfaces. To minimize perceptual bias during

sequential assessments, patients were shown their previous VAS markings prior to completing each new measurement.

All data were analyzed using IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables. Normality was assessed using the Shapiro-Wilk test. Preoperative and postoperative VAS scores were significantly non-normally distributed; non-parametric methods were therefore applied throughout. Between-group comparisons of postoperative VAS scores at 24 hours and 3 months were performed using the Kruskal-Wallis H test. Stratified subgroup analyses were conducted by gender and by cavity class using the Kruskal-Wallis test within each stratum. Pairwise comparisons of pre-operative VAS scores across groups were performed using the Mann-Whitney U test. The statistical significance thres-hold was set at alpha=0.05.

RESULTS

A total of 160 participants were enrolled (Table II) and comprised of 76 males (47.5%) and 84 females (52.5%), with an equal distribution of cavity classes: 80 Class I (50.0%) and 80 Class II (50.0%) restorations. The mean age was 29.49±4.31 years (range: 21-40 years). Preoperative VAS scores ranged from 30.0 to 90.0 mm (mean: 57.26±14.33 mm). A chi-square test revealed a statistically significant association between participant gender and cavity class ($\chi^2=28.97$, df=1, $p<0.001$). Female participants disproportionately presented with Class I cavities (n=59; 36.9%), whereas male participants more frequently presented with Class II cavities (n=55; 34.4%).

The results revealed a marked reduction in Visual Analog Scale (VAS) pain scores across all restoration protocols at the three-month follow-up. While pre-operative baseline pain levels varied among the cohorts nearly all materials demonstrated excellent efficacy in mitigating sensitivity over time (Table II).

Given that Shapiro-Wilk testing confirmed non-normal distribution of VAS scores at both the 24-hour and three-month, non-parametric Kruskal-Wallis analysis was applied for all between-group comparisons.

Inter-group analysis at the 24-hour interval using the Kruskal-Wallis test revealed significant differences in sensitivity levels across the four restorative strategies. Pairwise comparisons with Bonferroni correction demonstrated that the self-etch adhesive protocol resulted in

Table II: Median and IQR of VAS scores by restoration group

Restoration Group	Pre-Op VAS Median (IQR)	Post-Op VAS 7 Days Median (IQR)	Post-Op VAS 48 Hours Median (IQR)	Post-Op VAS 7 Days Median (IQR)	Post-Op VAS 3 Months Median (IQR)
Etch & Rinse	56 (4.00)	5.00 (2.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Self-Etch	41 (2.50)	2.00 (1.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
GIC	67 (16.25)	12.00 (5.00)	0.00 (0.00)	0.00 (0.00)	0.00 (45.00)
Activa Bioactive	65.5 (25.0)	5.00 (48.75)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

VAS: Visual Analog Scale; GIC: Glass Ionomer Cement; IQR: Inter quartile range

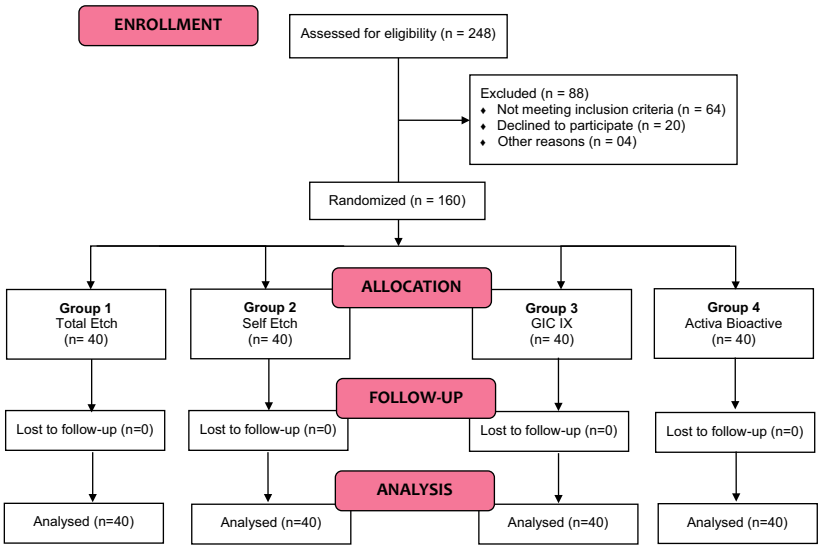

Figure 1: CONSORT Flow Diagram

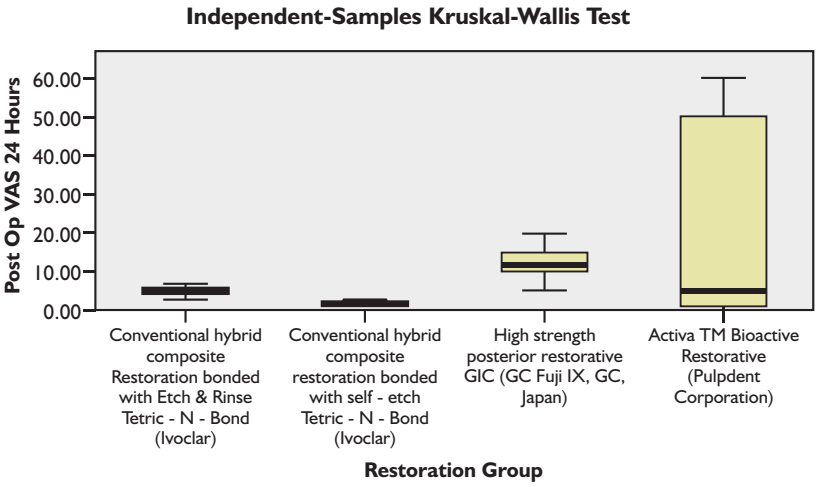

Figure 2: Pairwise comparison for the 24-hour mark

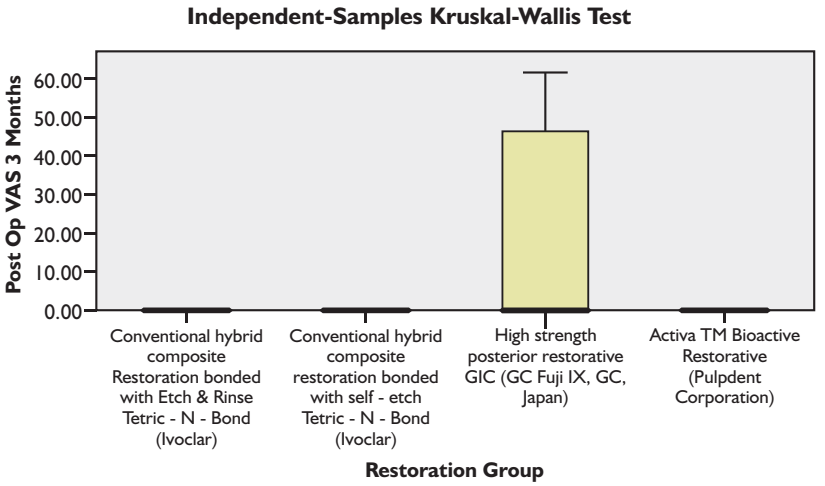

Figure 3: Pairwise comparison for the 3 Months

significantly lower sensitivity compared to all other groups ($p<0.001$). Conversely, the high-strength GIC group exhibited significantly higher VAS scores than all other cohorts ($p<0.001$). No statistically significant difference was observed between the etch-and-rinse and bioactive restorative groups ($p=1.000$) [Figure 2].

At the final three-month follow-up, no statistically significant differences were observed when comparing the etch-and-rinse, self-etch, and bioactive resin groups to one another ($p=1.000$). However, the high-strength GIC group showed significantly higher sensitivity levels compared to all other restorative protocols ($p<0.001$) [Figure 3].

There were no statistically significant differences in reported VAS scores between males and females at 24 hours, 48 hours, and 7 days. However, a highly significant difference re-emerged at the 3-month follow-up ($p<0.001$), where male patients demonstrated significantly higher levels of sensitivity compared to female patient. Subgroup analysis was conducted using the Mann-Whitney U test stratified by restorative material. The analysis revealed that patient gender had no statistically significant influence on pre-operative or post-operative sensitivity at any time interval for the etch-and-rinse composite, self-etch composite, or bioactive resin groups ($p>.05$). Within the GIC cohort, male patients reported significantly higher baseline pre-operative sensitivity ($p<0.001$) compared to females. Males in the GIC group experienced significantly higher post-operative sensitivity at the 24-hour mark ($p<0.001$) and exhibited sustained sensitivity at the 3-month final follow-up ($p<0.001$).

The results of impact of cavity type demonstrated that for conventional hybrid composites (both etch-and-rinse and self-etch) and bioactive resin restorations, cavity classification was not a significant ($p>0.05$), with both classes achieving absolute pain resolution by the 48-hour mark. In contrast, the high-strength GIC group exhibited significant sensitivity. Class I cavities were associated with significantly higher pre-operative baseline scores ($p<0.001$) and immediate (24-hour) post-operative sensitivity ($p<0.001$) compared to Class 2 restorations. Furthermore, sensitivity remained at the 3-month final follow-up ($p<0.001$) in Class I GIC restorations.

DISCUSSION

This randomized controlled trial demonstrated that postoperative dentinal sensitivity decreased over time with all four restorative strategies. The self-etch resin composite produced the lowest immediate postoperative sensitivity, whereas high-strength glass ionomer cement exhibited the highest sensitivity at 24 hours and remained the only material associated with persistent sensitivity at the three-month follow-up. In contrast, total-etch resin composite and bioactive resin restoration showed comparable postoperative sensitivity, with complete resolution by three months. Subgroup analyses further indicated that persistent sensitivity in the high-strength GIC group was more pronounced in male patients and Class I restorations.

The lower immediate postoperative sensitivity observed with the self-etch adhesive system is consistent with the established principles of dentin bonding and the hydrodynamic theory of dentinal sensitivity. Self-etch adhesives use mild acidic monomers that partially preserve the smear layer, creating a physiological seal over dentinal tubules and reducing fluid movement. In contrast, the total-etch technique completely removes the smear layer and may produce a demineralized dentin zone that is not fully infiltrated by adhesive resin, permitting greater dentinal fluid movement and consequently higher postoperative sensitivity. This mechanism is well-supported by literature that reports lower immediate sensitivity with self-etch systems in posterior composite restorations."[11,12] It is important to acknowledge, however, that meta-analyses Fang K, et al.,[1] have not found statistically significant differences in postoperative sensitivity between self-etch and total-etch adhesive systems overall.

The significant difference observed at 24 hours may be attributed to the lower baseline VAS scores in the self-etch group and the early protective effect of smear layer preservation, which reduces dentinal fluid movement. By three months, both self-etch and total-etch groups showed complete resolution of postoperative sensitivity, consistent with previous meta-analytic evidence. Therefore, the early advantage of the self-etch system should be interpreted cautiously because of the baseline imbalance between the study groups.

Bioactive resin produced the highest VAS score at 24 hours, though with inter-individual variability. Within-group

distribution reveals a bimodal pattern; 8 participants (20.0%) reported zero sensitivity, while 11 (27.5%) reported scores exceeding the 30 mm clinical threshold, with the remaining 21 participants distributed in the sub-threshold range. This variability suggests that bioactive resin is a technique-sensitive material whose clinical performance depends on meticulous procedural execution. Because its placement requires an etching step, dentinal tubules remain susceptible to hydrodynamic fluid movement. Suboptimal etching, moisture control, or material mixing may compromise the early sealing effect and increase postoperative sensitivity, whereas precise clinical technique allows the rubberized resin matrix and bioactive ion release to provide effective dentinal sealing and minimal postoperative sensitivity. Clinicians using bioactive resin should be aware of this technique sensitivity and should counsel patients that initial post-operative discomfort, if it occurs, typically resolves by 48 hours.[7]

Glass Ionomer produced high and more consistent sensitivity at 24 hours, which is attributable to the material's initial low pH during setting. GIC matures through an acid-base reaction between polyacrylic acid and fluoro-alumino-silicate glass particles. During the early setting phase, the acidic environment at the dentin interface may transiently increase tubular fluid osmolarity and permeability, stimulating hydrodynamic pain pathways. This is supported by Khan M, et al.,[13] who demonstrated that conventional GIC produces significantly greater micro-leakage scores than resin-modified alternatives during the early post-set period, and by another study which attributed GIC's early sensitivity to its incomplete ionic crosslinking in the initial hours following placement.[14]

The observation that all participants across all four material groups recorded absence of VAS sensitivity score at 48-hour and 7-day time points. From methodology perspective, the protocol of showing participants their previous VAS markings prior to each new assessment may have introduced a form of psychological anchoring. When a patient who marked 10–15 mm on day one is asked to re-rate on day two while viewing their prior mark, cognitive pressure to demonstrate recovery may anchor subsequent ratings toward zero, even where low-level residual discomfort persists. This effect is compounded by patient diaries; when sensitivity no longer actively impairs function, patients may record zero as response rather than engaging critically with the analogue scale. The re-emergence of sensitivity at 3 months during a supervised clinical assessment is consistent with this interpretation, as clinical recall assessments are less susceptible to anchoring than take-home diaries.[15]

The recurrence of sensitivity in GIC is consistent with the established bio-mechanical limitations of conventional high-strength glass ionomer cement in load-bearing posterior restorations. GIC, while exhibiting excellent fluoride release and chemical adhesion during the early post-set phase, has a low modulus of elasticity relative to composite resin, which makes it susceptible to interfacial stress accumulation under repetitive occlusal loading. Over a period of weeks to months, cyclic masticatory forces may induce progressive fatigue of the GIC-dentin bond, resulting in microscopic interfacial gaps through which dentinal fluid can again flow freely, re-activating the hydrodynamic pain mechanism. This interpretation aligns with the findings of studies which identified marginal adaptation failure as the principal mechanism underlying late-onset GIC sensitivity in posterior permanent teeth.[13,14,16,17] The statistically significant interaction between GIC and type of cavity preparation is explained by the configuration factor (C-factor) of polymerization shrinkage stress, a concept that has direct relevance even to GIC restorations that set through an acid-base reaction rather than light-polymerization.[18]

A particularly notable finding was that all 17 participants in Group 3 who reported sensitivity at 3 months had also reported sensitivity at 24 hours. This suggests that the 3-month GIC sensitivity recurrence does not represent a new pathological process but rather a continuation or re-emergence of sensitivity in the same subset of patients who had already demonstrated a heightened hydrodynamic response to GIC at the early time point. Clinicians may therefore be able to identify GIC patients at higher risk of 3-month sensitivity based on their 24-hour response pattern.

An important consideration when interpreting the reported sensitivity levels is their relationship to patient functional impairment and well-being. At 24 hours, Groups 1, 2, and 3 recorded mean VAS scores substantially below the 30 mm clinical significance threshold and unlikely to represent functionally limiting discomfort. Group 1 maximum score across all participants was 7 mm, and Group 2 maximum was 3 mm, values that most patients would characterize as barely perceptible. Even Group 3 maximum of 20 mm at 24 hours, while higher, remained sub-threshold. The only group in which clinically significant sensitivity (VAS > 30 mm) was observed at 24 hours was Group 4, affecting 11 of 40 participants. At 3 months, clinically significant recurrence was confined to 12 of 40 Group 3 participants (30.0%). These findings suggest that mean VAS scores, particularly in the presence of substantial within-group variability, may overestimate the clinical burden of postoperative sensitivity, as most participants experienced no significant functional discomfort. Future studies should complement VAS assessments with patient-reported outcome measures evaluating functional limitations, such as difficulty with eating, drinking, or daily activities, to better determine the clinical relevance of postoperative sensitivity.

Several limitations of the present study must be considered when interpreting its findings and their generalizability. The most significant methodological limitation is the non-equivalence of pre-operative VAS scores across the four restoration groups, because teeth with lower baseline sensitivity inherently represent less inflamed pulpal tissue with fewer patent tubules, the 24-hour superiority of the self-etch group cannot be attributed solely to material-

mediated tubular occlusion. A related limitation is the unequal distribution of tooth arch location across groups, Maxillary and mandibular molars differ in pulp chamber anatomy, root morphology, and the anatomy of the dentin-enamel junction, all of which may influence sensitivity responses independent of the restorative material. The use of a single operator, while reducing inter-operator variability and ensuring consistency in cavity preparation and restorative technique, limits the external validity of these findings to broader clinical settings where multiple practitioners with varying levels of experience perform restorations. In real-world practice, differences in adhesive application technique, acid etching precision, incremental placement discipline, and material handling may produce sensitivity outcomes that differ substantially from those observed under the controlled, single-operator conditions of this trial. Multicenter studies with multiple calibrated operators would be required to establish the generalizability of these findings across routine clinical practice. The non-probability consecutive sampling method, conducted at a single institution, further constrains the external validity of the study population. Finally, a patient-administered visual analogue scale is inherently subjective and susceptible to individual variation in pain.

CONCLUSION

Self-etch adhesive composite was associated with the lowest postoperative sensitivity at 24 hours in this study; however, this finding should be interpreted with caution given the significantly lower preoperative baseline VAS scores in this group. GIC is associated with clinically significant late-onset sensitivity recurrence at 3 months, particularly in Class I preparations and in male patients. Bioactive resin demonstrated complete and durable resolution of sensitivity by 48 hours, with zero sensitivity maintained at 3 months. The universal zero sensitivity at 48 hours and 7 days is due to anchoring effect, whereby showing participants their prior VAS markings may have compressed subsequent ratings toward zero once acute discomfort had begun to resolve, diary fatigue in which patients default to zero when sensitivity is no longer functionally disruptive

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AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

PR: Conception and study design, acquisition of data, approval of the final version to be published

MM: Conception and study design, critical review, approval of the final version to be published

KK & RK: Analysis and interpretation of data, critical review, approval of the final version to be published

SS & S: Acquisition of data, drafting the manuscript, approval of the final version to be published

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

Authors declared no conflict of interest, whether financial or otherwise, that could influence the integrity, objectivity, or validity of their research work.

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DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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