

Research Article

Comparative Evaluation of Giomer-Based and Nanohybrid Restorative Materials in Carious and Non-Carious Cervical Lesion Restorations: A 36-Month Prospective Longitudinal Randomized Controlled Clinical Trail Study Assessing Clinical, Periodontal and Oral Biological Manifestation Attributes.

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ABSTRACT

Background: Contemporary restorative dentistry increasingly emphasizes materials that combine esthetic and mechanical performance with biological activity. Giomer-based restorative materials incorporate surface pre-reacted glass-ionomer fillers capable of releasing multiple ions, whereas nanohybrid resin composites provide favorable esthetics, polishability, and mechanical properties. Comparative evidence regarding their medium-term performance across carious and non-carious lesions, particularly when periodontal and biological outcomes are considered alongside conventional clinical criteria, remains limited.

Objective: To compare the 36-month esthetic, functional, biological, periodontal, and overall clinical performance of Giomer-based and Nanohybrid restorative materials in carious and non-carious lesions intracoronary restorations.

Methods: This prospective longitudinal randomized controlled clinical trial study was conducted at Tertiary care Hospital from 01st October 2023 to 01st July 2026, primarily included 750 restorations, equally divided between Giomer-based and Nanohybrid restorative material groups (375 each). The intracoronary restorations comprised 403 carious and 347 non-carious lesions. Clinical performance was assessed over 36 months using standardized criteria covering surface luster, staining, marginal staining, color match, anatomical form, retention, fracture, marginal adaptation, postoperative sensitivity, recurrent caries, tooth integrity, gingival inflammation, bleeding on probing, and overall periodontal response. Categorical variables were compared using the chi-square or Fisher's exact test, and Cramer's V was used to quantify effect size where appropriate. A p-value <0.05 was considered statistically significant.

Results: Overall clinical success was significantly higher with Giomer-based restorations as compared to Nanohybrid restorations (92.3% vs 86.9%; p=0.017, Cramer's V=0.087). Giomer-based restorations demonstrated significantly better marginal staining (90.1% vs 84.8%; p=0.027) and marginal adaptation (90.9% vs 85.3%; p=0.018). Gingival inflammation (15.7% vs 22.4%; p=0.020) and bleeding on probing (13.9% vs 20.8%; p=0.012) were less frequent around Giomer-based restorations. Overall periodontal acceptability was also higher in the Giomer-based restorations group (85.3% vs 78.4%; p=0.014). Recurrent/secondary caries occurred in 4.8% of Giomer-based

restorations and 8.3% of Nanohybrid- restorations, although this difference did not reach statistical significance ($p=0.055$). Other esthetic and biological parameters were generally comparable.

Conclusion: Both Giomer-based and Nanohybrid-restorative materials demonstrated satisfactory 36-month clinical performance in carious and non-carious lesions. Giomer-based restorations showed modest advantages in marginal integrity, periodontal response, and overall clinical success. Longer-term controlled studies are required to determine whether these differences persist and result in meaningful improvements in restoration longevity. When long-term durability, clinical longevity, functional, periodontal and oral biological parameters are a primary consideration, Giomer based restorations have provided; clinically acceptable outcomes and are preferred favorably as compare to Nanohybrid restorative materials in carious and non carious lesion restorations.

Keywords: Giomer, Nanohybrid Composite, S-PRG Filler, Intracoronal Restorations, Carious Lesions, Non-Carious Cervical Lesions, Periodontal Response, Clinical Performance.

CLINICAL RELEVANCE

The clinical significance of this study lies in providing comparative evidence regarding the long-term esthetic, functional, biological, and periodontal performance of Giomer-based and Nanohybrid resin composite restorations in carious and non-carious dental lesions. For restorative dental specialists, the findings may support evidence-informed material selection, particularly in cervical lesions where marginal adaptation, retention, moisture control, and periodontal compatibility are important considerations. General Dental Practitioners may benefit from a clearer understanding of the clinical performance and potential advantages of these restorative materials in routine restorative procedures. For Endodontists, the findings are relevant to the preservation of cervical tooth structure, the management of dentine hypersensitivity, and the maintenance of marginal integrity in teeth requiring restorative treatment. The observed differences in marginal adaptation, gingival response, and overall clinical success may assist clinicians in selecting suitable restorative approaches while emphasizing the importance of adhesive protocols, lesion characteristics, and long-term follow-up emphasizing success in contemporary and modern aesthetic and restorative dentistry.

INTRODUCTION

Direct restorative dentistry has progressively moved toward conservative treatment approaches that preserve sound tooth structure while restoring esthetics, function, and biological compatibility. Resin-based composites are widely used because of their adhesive properties, favorable esthetics, ability to reproduce natural tooth morphology, and suitability for minimally invasive cavity preparation. Nevertheless, the longevity of direct restorations may be affected by polymerization stresses, marginal gap

formation, microleakage, surface degradation, staining, loss of marginal adaptation, recurrent caries, and deterioration of surrounding oral tissues. Pawar et al. demonstrated differences in microleakage among restorative materials used for Class II restorations, emphasizing that maintenance of the tooth-restoration interface is fundamental to long-term success [1]. Restorative material exposure may also influence biological responses; Asim et al. reported variations in oxidative stress, inflammatory activity, and cellular injury associated with different restorative materials [2]. In addition, Pervez et al. compared bulk-fill flowable and conventional nanohybrid composites in posterior teeth, highlighting the continued importance of material composition and handling characteristics in restorative outcomes [3]. These findings support a broader concept of restoration success that includes not only retention and mechanical durability but also marginal, biological, and tissue-related outcomes.

Non-carious cervical lesions are characterized by the progressive loss of dental hard tissue in the cervical region near the cemento-enamel junction without direct involvement of the dental caries process. Their development is generally multifactorial, involving mechanical wear, chemical dissolution, and potentially biomechanical stress-related factors. Abrasion is defined as pathological mechanical wear caused by repeated contact with external objects or materials, particularly inappropriate toothbrushing techniques, excessive brushing pressure, and abrasive dentifrices. Clinically, abrasion-related lesions frequently present as smooth, shallow, or well-defined cervical defects, although their appearance may vary according to the duration and intensity of mechanical exposure. The resulting exposure of cervical dentin may produce hypersensitivity, compromise esthetics, and increase the complexity of adhesive restorative

treatment. The clinical distribution and severity of these lesions may also be influenced by age, oral hygiene behavior, tooth position, and the presence of gingival recession.

Erosion, commonly referred to as erosive tooth wear, represents the chemical dissolution of enamel and dentin through exposure to acids of non-bacterial origin. Extrinsic sources include acidic foods, carbonated beverages, citrus products, and other dietary acids, whereas intrinsic sources primarily involve gastric acid exposure associated with gastroesophageal reflux or recurrent vomiting. Erosion-associated cervical defects often present with smooth, rounded, or concave surfaces and varying degrees of dentin exposure. Continued acid exposure may alter the surface characteristics of dental hard tissues, thereby influencing adhesive interactions and restorative longevity. Successful management therefore requires consideration of the underlying acid exposure, conservative restoration of clinically significant defects, and preventive strategies aimed at reducing further tissue loss. In the cervical region, erosion frequently coexists with abrasion, resulting in combined patterns of tooth surface deterioration that cannot always be attributed to a single etiological factor [4].

Abfraction has been proposed as a form of cervical tooth surface loss associated with stress concentration and flexural deformation under occlusal loading. Such lesions are frequently described as wedge-shaped defects with relatively sharp internal angles, commonly observed in cervical regions subjected to complex functional stresses. However, the independent role of occlusal loading in producing these defects remains controversial, and wedge-shaped morphology alone does not establish an abfraction mechanism. Current understanding emphasizes the possibility that mechanical abrasion, erosive processes, and biomechanical influences may interact in the development and progression of non-carious cervical lesions. Consequently, comprehensive clinical evaluation should consider lesion morphology, oral hygiene practices, dietary factors, gingival recession, occlusal characteristics, and dentin hypersensitivity rather than relying exclusively on the visual appearance of the cervical defect.

The anatomical distribution of cervical lesions is another important consideration in restorative dentistry. Maxillary and mandibular central incisors, lateral incisors, canines, premolars, and molars may be affected by

carious and non-carious cervical defects, although their prevalence and clinical presentation vary according to anatomical and functional characteristics. Premolars and other teeth exposed to repeated mechanical or chemical challenges may develop cervical tissue loss that complicates restorative management. Differences in enamel thickness, dentin exposure, cervical contour, gingival position, and accessibility may influence isolation, adhesive application, restorative adaptation, and long-term clinical behavior. Identification of the affected tooth and dental arch is therefore clinically relevant when selecting restorative materials and planning conservative treatment[5, 6].

The restoration of non-carious cervical lesions presents specific challenges because cervical margins may extend onto dentin or cementum, where adhesive bonding can be less predictable than on enamel. In addition, the absence of conventional macromechanical retention, exposure to functional loading, limited access for isolation, and proximity to gingival tissues may influence restoration retention and marginal integrity. Restorative intervention is generally considered when lesions are associated with persistent hypersensitivity, progressive structural loss, esthetic concerns, plaque-retentive defects, or other clinically significant problems. Management should also address contributing factors, including traumatic toothbrushing, dietary acid exposure, and other patient-specific conditions. The selection of an appropriate restorative material should therefore consider not only mechanical strength and esthetics but also marginal adaptation, biological compatibility, surface characteristics, and the response of adjacent periodontal tissues [7].

Carious and non-carious lesions represent different clinical challenges and may respond differently to restorative treatment. Non-carious cervical lesions are particularly demanding because of their multifactorial etiology, cervical location, variable enamel and dentin margins, limited mechanical retention, and exposure to flexural and occlusal stresses. A systematic review by Teixeira et al. reported a weighted prevalence of non-carious cervical lesions of approximately 46.7% in adults, demonstrating their considerable clinical burden [7]. Cervical lesions may also be associated with dentine hypersensitivity, gingival recession, and compromised periodontal conditions. Dentine

hypersensitivity continues to be an important but frequently underestimated clinical problem, particularly where dentin or root surfaces are exposed [8]. The use of silver diamine fluoride has expanded as a minimally invasive strategy for management of root caries and dentine hypersensitivity, with recent author-supplied studies supporting its role in both situations [5, 6]. At the same time, periodontal status may influence treatment outcomes because plaque retention, gingival inflammation, and changes in peri-alveolar tissues can adversely affect the local restorative environment. Mahajani et al. examined salivary antioxidant capacity in chronic periodontitis [9], while Khan Jadoon et al. demonstrated that tissue-preserving surgical techniques can improve peri-alveolar tissue integrity and healing, reinforcing the importance of preserving surrounding tissues during dental treatment [4].

The development of Giomer- based restorative materials reflects the growing interest in materials that combine conventional resin-composite properties with additional ion-releasing characteristics. Gionomers contain surface pre-reacted glass-ionomer (S-PRG) fillers embedded within a resin matrix. These fillers can release multiple ions, including fluoride, strontium, sodium, silicate, borate, and aluminum, and have been associated experimentally with acid buffering, remineralization, antibacterial activity, and modification of the local biological environment [10, 11]. Imazato et al. described the multiple-ion releasing behavior of S-PRG fillers and their potential roles in strengthening dental tissues, neutralizing acids, inhibiting microorganisms, and promoting mineralization [10]. Experimental evidence has also demonstrated that higher concentrations of S-PRG filler can enhance remineralization of initial enamel caries lesions [11]. More broadly, fluoride-releasing restorative materials comprise a heterogeneous group with varying ion-release characteristics, resin compositions, and mechanical properties, indicating that the term "bioactive" should be interpreted cautiously and supported by clinical evidence rather than ion release alone [12].

These characteristics are of particular interest in cervical restorative dentistry, where the restoration-tooth interface may be exposed to acidic conditions, moisture-related challenges, mechanical stresses, and adjacent gingival tissues. The potential ion-releasing properties of Giomer materials may contribute to a

favorable restorative environment, although their clinical benefits depend on multiple factors, including adhesive performance, lesion configuration, oral hygiene practices, and appropriate restorative techniques. Nanohybrid resin composites, in comparison, provide favorable esthetics, polishability, mechanical strength, and adaptability to different cavity configurations. Both restorative systems therefore offer potential advantages in the management of carious and non-carious lesions, making their comparative evaluation important for evidence-based restorative material selection.

Clinical studies increasingly suggest that Giomer-based restorations can provide acceptable medium- and long-term performance. Ozer et al. reported favorable three-year clinical performance of conventional and flowable Giomer restorative materials, with satisfactory retention and clinical behavior [13]. Five-year evaluation of fluoride-releasing Giomer-based materials similarly demonstrated acceptable clinical performance without significant deterioration in the major evaluated criteria [14]. A systematic review and meta-analysis by Limonge Neto et al. concluded that Giomer restorations generally show clinical outcomes comparable with other conventional restorative materials in permanent teeth [15]. Long-term evidence is also available: Tian et al. reported comparable survival and clinical performance between a Giomer restorative system and a nanofilled resin composite over eight years, with similar retention, marginal adaptation, marginal staining, and overall survival probabilities [16]. These findings indicate that Giomer materials are clinically viable alternatives to conventional resin composites, but they do not establish universal superiority, particularly because adhesive systems, lesion characteristics, oral hygiene, operator technique, and patient-related factors substantially influence restoration longevity.

Despite these encouraging findings, further comparative clinical evaluation remains important because the performance of restorative materials may vary according to lesion characteristics, cervical margin location, dentin exposure, functional loading, and surrounding periodontal conditions. In particular, non-carious cervical lesions associated with abrasion, erosion, and possible abfraction mechanisms present complex restorative challenges that may not be fully reflected by conventional assessments of retention and esthetics alone. Evaluation of

marginal integrity, secondary caries, postoperative sensitivity, gingival inflammation, and periodontal response may provide a more comprehensive understanding of restoration performance. Such evidence is relevant to restorative dental specialists, general dental practitioners, and endodontists involved in the conservative management of cervical tooth structure loss.

Therefore, the present prospective longitudinal randomized controlled clinical trial study aimed to evaluate the 36-month esthetic, functional, biological, periodontal, and overall clinical performance of Giomer-based and nanohybrid resin composite restorations in carious and non-carious dental lesions. The study sought to determine whether differences in restorative material characteristics were associated with clinically meaningful variations in marginal adaptation, restoration retention, postoperative sensitivity, recurrent caries, gingival response, and overall clinical success.

METHODOLOGY

Study Design and Setting

This prospective longitudinal comparative clinical study was conducted at Tertiary care Hospital from 01st October 2023 to 01st July 2026 to compare the clinical performance of Giomer-based and Nanohybrid Resin composite intracoronal restorations in carious and non-carious dental lesions. Patients requiring direct restorative treatment were recruited consecutively from the Outpatient restorative dental service. A total of 750 restorations were included, with 375 restorations allocated to each restorative material group. The study included cervical restorative lesions involving maxillary and mandibular anterior and posterior teeth, with clinical consideration of individual tooth categories, including central incisors, lateral incisors, canines, premolars, and molars. Particular attention was given to the clinical challenges associated with non-carious cervical lesions, including abrasion, erosion, and abfraction-related tooth surface loss. Eligible restorations were followed prospectively throughout the study period and evaluated for esthetic, functional, biological, and periodontal outcomes.

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the relevant Institutional Review Board/Ethical

Review Committee of the respective Institute before commencement of the study, and written informed consent was obtained from all participants prior to enrolment and treatment. Patient confidentiality was maintained throughout clinical assessment, restorative treatment, follow-up, data handling, and statistical analysis. Individual clinical information was treated confidentially and used only for the purposes of the approved research.

The sample size was calculated for comparison of two independent proportions representing the anticipated clinical success rates of Giomer-based and Nanohybrid restorations. Based on previous comparable clinical evidence, expected clinical success proportions of approximately 90% for Giomer restorations and 83% for Nanohybrid restorations were considered. With a 95% confidence level, 80% statistical power, a two-sided significance level of 5%, and equal allocation between the two study groups, the sample size was calculated using the formula: $n = [Z_{\alpha/2}\sqrt{2\bar{P}(1-\bar{P})} + Z_{\beta}\sqrt{P_1(1-P_1) + P_2(1-P_2)}]^2 / (P_1-P_2)^2$, where $P_1 = 0.90$, $P_2 = 0.83$, $\bar{P} = 0.865$, $Z_{\alpha/2} = 1.96$, and $Z_{\beta} = 0.84$. The calculated minimum sample size was approximately 373 restorations per group, corresponding to 746 restorations overall. This was rounded upward to a final sample of 750 restorations, with 375 restorations included in each group.

Inclusion and Exclusion Criteria

Patients of either gender requiring restoration of clinically diagnosed carious or non-carious lesions were screened for eligibility. Teeth were included when the lesion was suitable for direct adhesive restoration, sufficient sound tooth structure remained to permit predictable restoration, adequate isolation could be achieved, and the tooth was clinically restorable. Eligible dental sites included maxillary and mandibular anterior and posterior teeth, encompassing central and lateral incisors, canines, premolars, and molars where direct cervical restorative treatment was clinically indicated. Non-carious cervical lesions were considered in relation to their possible mechanical, chemical, and biomechanical contributing factors, including abrasion, erosion, and abfraction. Teeth with irreversible pulpitis, pulpal necrosis, periapical pathology, extensive structural destruction requiring indirect rehabilitation, severe periodontal attachment loss, excessive mobility, or an indication for extraction were excluded.

Patients unable to provide informed consent or unwilling to attend scheduled follow-up visits were also excluded. The final analysis comprised 750 restorations, including 403 carious and 347 non-carious lesions.

Restorative Material Groups

The restorations were divided into two equal comparative groups according to the restorative material used. Group I consisted of 375 restorations treated with a Giomer-based restorative material, while Group II consisted of 375 restorations treated with a Nanohybrid resin composite material. The Giomer group included 205 carious and 170 non-carious lesions, whereas the Nanohybrid group included 198 carious and 177 non-carious cervical lesions. The Giomer-based restorative material incorporated surface pre-reacted glass-ionomer (S-PRG) filler technology, while the comparison material was a Nanohybrid resin composite material containing nanoscale and conventional filler particles within a resin matrix. The same restorative system, adhesive protocol, placement technique, curing procedure, and finishing and polishing approach were maintained consistently within each study group.

Clinical Examination and Lesion Assessment

Before restorative treatment, demographic information, relevant medical and dental history, lesion type, tooth location, and baseline clinical characteristics were recorded using a structured data collection form. Clinical examination was performed under adequate illumination after cleaning and drying the tooth surface, and radiographic examination was undertaken whenever clinically indicated.

Carious lesions were identified according to the clinical features of dental hard-tissue demineralization and cavitation. Non-carious cervical lesions were characterized by loss of dental hard tissue near the cemento-enamel junction in the absence of a primary carious process. These lesions may develop through the combined effects of mechanical abrasion, chemical erosion, and biomechanical stresses. Abrasion refers to pathological mechanical wear caused by external factors, commonly including excessive or improper toothbrushing and abrasive dentifrices. Clinically, abrasion-related cervical defects may appear smooth, shallow, or sharply demarcated depending on the duration and intensity of the mechanical insult.

Erosion, also described as erosive tooth wear, involves progressive chemical dissolution of enamel and dentin by acids of non-bacterial origin. These acids may arise from frequent consumption of acidic beverages and foods or from intrinsic gastric sources. Erosion-associated lesions may present as smooth, rounded, or concave defects with varying degrees of cervical dentin exposure. Abfraction describes a proposed mechanism of cervical hard-tissue loss associated with stress concentration and tooth flexure during occlusal loading. Such lesions may appear wedge-shaped with relatively well-defined margins; however, the independent contribution of occlusal stresses to lesion development remains uncertain, and clinical morphology alone does not establish abfraction as the exclusive cause.

The recognition of these non-carious cervical lesion patterns was clinically relevant to restorative treatment because the configuration of cervical defects, exposed dentin surfaces, proximity to gingival tissues, and presence of occlusal stresses may affect bonding, marginal adaptation, retention, and postoperative sensitivity. The study's original Results classified these lesions collectively as non-carious; therefore, abrasion, erosion, and abfraction are discussed as possible clinical mechanisms rather than separately quantified diagnostic groups.

Restorative Procedure for Carious Lesions and the Protocol with the Armamentarium

Carious lesions were managed through conservative removal of infected carious tissue while preserving sound enamel and dentin. Before cavity preparation, the affected tooth was examined for lesion extent, cavitation, remaining tooth structure, pulpal proximity, and suitability for direct adhesive restoration. An adequate isolation with Rubberdam and cotton rolls was performed to enhance excellent visibility and accessibility of the respective lesion prior to the restoration protocol. The tooth surface was cleaned, and appropriate moisture control and other isolation measures were applied to minimize contamination during bonding and restorative material placement.

Cavity preparation followed the principles of minimally invasive restorative dentistry. Carious tissue was removed conservatively using suitable rotary or hand instruments comprising of high speed carbide burs (MANI-#02 round bur, #330 bur), confined to cervical

one third of tooth, 1mm away from the gingival margin and following the tooth contour, while preserving the remaining healthy dental structure. A depth of 1.2 to 1.5mm of the cavity was prepared; perpendicular to the surface. The depth of the cavity was checked with a periodontal probe with markings and the smoothness of pulpal floor was well evaluated. Lastly, beveling of enamel margins was done using a small flame shaped or football shaped bur (MANI-F0-32) diamond bur or short flame bur, cutting diamond point held at 45 degrees mesially and distally, incisal and proximal enamel margins. The prepared cavity was inspected for residual infected tissue, unsupported enamel, and the adequacy of the restorative margins. Where indicated by lesion depth, appropriate pulpal protection was considered. The final prepared cavity was finished with non-fluoride pumice. Following cavity preparation, enamel and dentin surfaces were conditioned according to the adhesive system used. The bonding system used was Scotchbond™ Universal Adhesive (3M/ESPE, St. Paul, MN, USA), total-etch adhesive system containing MDP phosphate monomer, dimethacrylate resins, HEMA, and Vitrebond™ copolymer about 35-37% phosphoric acid applied for 15 seconds. The bonding agent was applied in accordance with the manufacturer's instructions and polymerized using an appropriate light-curing unit for 10 to 15 seconds. The material, BEAUTIFIL II LS (Shofu Inc., Kyoto, Japan), Giomer –based material pre-reacted glass-ionomer (S-PRG) filler with a polymer matrix composed of low-shrinkage urethane diacrylate, Bis-MPEPP, Bis-GMA, and TEGDMA was used. The Nanohybrid –based material used was 3M/ESPE Filtek Supreme Universal Restorative (3M/ESPE, St. Paul, MN, USA), formulated from Bis-GMA, UDMA, TEGDMA, and Bis-EMA(6), with non-agglomerated/non-aggregated silica and zirconia nanofillers. The allocated restorative material was then placed and adapted to the prepared cavity. Incremental placement was used where indicated by cavity depth, restoration size, and material requirements. Each increment was light-cured according to the specified material protocol. Lastly, the finishing of the carious and non-carious cervical lesion restorations were done using (SHOFU INC., KYOTO, JAPAN) finishing kit comprising of medium grit, fine and ultrafine

burs, finishing discs, silicon rubber cups, finishing wheels and lastly (SHOFU INC., KYOTO, JAPAN) polishing paste applied on the restorations with the brushes. The final restoration was anatomically contoured, finished, and polished to establish acceptable marginal continuity, surface smoothness, and functional morphology.

Restorative Procedure for Non-Carious Cervical Lesions

Non-carious lesions were treated using a minimally invasive approach, avoiding unnecessary removal of healthy dental tissue. The restorative management of non-carious cervical lesions required particular attention to the anatomy of the cervical region, exposed dentin surfaces, proximity of the gingival margin, and the possible etiological influences of abrasion, erosion, and abfraction. The cervical defects were examined clinically to determine their configuration, depth, marginal characteristics, and suitability for adhesive restoration.

For abrasion-associated lesions, attention was directed toward the presence of mechanically worn enamel and dentin surfaces. The restorative approach emphasized preservation of remaining tooth structure, proper adaptation of restorative material to the cervical defect, and the establishment of a smooth surface to minimize plaque retention. Patients with clinical features suggesting mechanical wear could also benefit from appropriate advice regarding toothbrushing technique and abrasive habits.

For erosion-associated lesions, the cervical surfaces were assessed for acid-related tissue loss, exposed dentin, and the extent of the affected enamel margins. The clinical management emphasized conservative restoration of structurally compromised lesions, while recognition and control of dietary or intrinsic acid exposure remained important considerations for long-term stability. Restorative procedures were directed toward restoring lost cervical contour and protecting exposed dentin without unnecessary extension of the preparation.

For wedge-shaped cervical defects potentially associated with abfraction mechanisms, the treatment approach considered lesion geometry, dentin exposure, cervical margin configuration, and clinically relevant occlusal factors. Conservative preparation was preferred, and unnecessary removal of cervical tooth structure was avoided. Because cervical

lesions are commonly multifactorial, the restorative approach was based on clinical presentation and treatment requirements rather than assuming a single etiological mechanism.

Non-cavitated cervical lesions were assessed for the need for operative treatment on the basis of symptoms, structural integrity, progression, and esthetic or functional requirements. Lesions not requiring restoration could be managed by preventive measures and monitoring. Where restorative intervention was clinically indicated, the selected Giomer or Nanohybrid material was adapted to the cervical defect following the appropriate adhesive protocol.

Before adhesive application, the lesion surfaces were cleaned and isolated to achieve suitable moisture control. The adhesive system was applied according to the manufacturer's recommended procedure. The restorative material was subsequently placed into the cervical defect, with careful adaptation at the enamel and dentin margins and attention to the gingival extent of the restoration. Placement and polymerization were performed in accordance with the restorative material's clinical instructions. The restored surface was then finished and polished to reproduce the cervical contour of the tooth and avoid overhanging or irregular margins adjacent to periodontal tissues.

Finishing, Polishing, and Postoperative Evaluation

After completion of the restoration, finishing and polishing were performed using standardized instruments, and occlusal contacts were checked and adjusted when necessary. The operative protocol was standardized as far as possible to minimize variability related to material placement.

Particular attention was given to cervical marginal adaptation, surface smoothness, anatomical contour, and the relationship of the restoration to the adjacent gingival tissues. Excess restorative material and marginal irregularities were eliminated where present to minimize potential plaque accumulation and gingival irritation. Restorations were examined after placement to identify visible marginal defects, inadequate contour, surface irregularities, or immediate postoperative concerns.

Follow-Up and Clinical Evaluation

Clinical photographs were obtained at baseline and follow-up visits using camera system to document restoration condition. Participants were followed for 36 months after restoration placement. Clinical assessments were carried out at baseline and scheduled follow-up visits, with the principal outcome assessment performed at 36 months. Where complete longitudinal records were available, intermediate follow-up examinations were performed at 6, 12, and 24 months in addition to the final 36-month evaluation. At each visit, restorations were examined under standardized clinical conditions, with assessment of the restorative material, restoration-tooth interface, surrounding tooth structure, adjacent periodontal tissues, and patient-reported symptoms.

Clinical performance was evaluated using criteria based on the FDI/Hickel framework for direct restorations. The esthetic assessment included surface luster, surface staining, marginal staining, color match, anatomical form, and surface texture. Each parameter was categorized according to whether the restoration remained clinically acceptable at follow-up.

Functional performance was evaluated on the basis of complete retention, partial dislodgement, complete dislodgement, fracture or chipping, marginal adaptation, marginal defects, and the need for repair or replacement. A restoration that remained intact and clinically functional without requiring replacement was considered functionally acceptable. Complete restoration loss, major fracture, or deterioration requiring replacement was considered a clinically important failure.

In cervical restorations, marginal adaptation and retention were particularly important clinical parameters because the tooth-restoration interface may be influenced by cervical dentin characteristics, lesion morphology, adhesive performance, and functional loading. These considerations were relevant to the evaluation of both carious and non-carious lesions without requiring separate statistical categorization of abrasion, erosion, and abfraction.

Biological Outcome Assessment

Biological outcomes included postoperative sensitivity, recurrent or secondary caries, integrity of the restored tooth, pulpal symptoms, and adjacent mucosal reactions. Secondary or recurrent caries was diagnosed

on the basis of clinical examination, with radiographic assessment where indicated. Restorations without clinically relevant adverse biological findings were classified as biologically acceptable.

Postoperative sensitivity was considered particularly relevant in cervical lesions because exposed dentinal tubules and the proximity of restorative margins to the cervical region may contribute to sensitivity following restorative treatment. Assessment of biological acceptability therefore included consideration of both the restored dental tissues and the patient's clinical symptoms.

Periodontal Outcome Assessment

Periodontal tissues adjacent to restored teeth were evaluated for plaque accumulation, gingival inflammation, bleeding on probing, periodontal abnormalities, and overall periodontal response. Gingival inflammation and bleeding were assessed using consistent clinical examination procedures. Restorations with healthy surrounding periodontal tissues and without clinically significant inflammatory changes were considered periodontally acceptable.

Because cervical restorations are located close to the gingival margin, the periodontal assessment was relevant to determining whether restorative surface characteristics and marginal integrity were associated with local soft-tissue responses. Proper cervical contour, smooth finishing, and avoidance of gingival overhangs were important clinical considerations in the evaluation of both Giomer and nanohybrid restorations.

Overall Clinical Outcome Assessment

Overall clinical performance at 36 months was categorized as clinically excellent, clinically good, clinically satisfactory, repair required, or replacement required. For the principal analysis, restorations categorized as excellent, good, or satisfactory and remaining clinically serviceable without replacement were considered successful. Restorations requiring substantial corrective treatment or complete replacement were categorized as failures. Overall success was additionally assessed according to whether the original lesion was carious or non-carious.

This classification permitted evaluation of the comparative clinical performance of the two restorative materials while maintaining consistency with the predefined study

outcomes and the existing analysis of carious and non-carious lesions.

Examiner Standardization And Data Collection

Clinical evaluators were trained in the predefined scoring criteria before commencement of follow-up assessment. Representative cases were reviewed to standardize interpretation of acceptable and unacceptable restoration characteristics. Where more than one examiner participated, differences were resolved through reassessment and consensus. The same clinical definitions and evaluation procedures were maintained throughout the study to reduce measurement variability, and completed data collection forms were checked for accuracy and completeness before statistical entry.

Statistical Analysis

The Data was analyzed using IBM SPSS Statistics version 32.0. Categorical variables were summarized as frequencies and percentages, whereas continuous variables were expressed as mean $\pm$ standard deviation when normally distributed and as median with interquartile range when non-normally distributed. Normality of continuous variables was assessed using the Shapiro–Wilk test. The Pearson chi-square test was used to compare categorical variables between the Giomer and nanohybrid groups, while Fisher's exact test was applied when expected cell frequencies were insufficient. Cramer's V was reported where appropriate to describe the magnitude of association for categorical variables. Continuous variables were compared using the independent-samples t-test for normally distributed data and the Mann–Whitney U test for non-normal data. For repeated measurements across follow-up visits, an appropriate longitudinal method such as generalized estimating equations was used where inferential assessment across time was required. All tests were two-sided, and a p-value of less than 0.05 was considered statistically significant.

The principal comparative analyses focused on the clinical outcomes of Giomer-based and Nanohybrid restorations and overall success according to carious and non-carious lesion type. Abrasion, erosion, and abfraction were not subjected to separate inferential analyses because the existing Results did not provide lesion-subtype-specific observations. No

additional tooth-specific or gender-specific subgroup comparisons were introduced.

RESULTS

A total of 750 restorations were included in this analysis, with 375 restorations evaluated in the Giomer group and 375 in the Nanohybrid composite group. The clinical assessment covered demographic and lesion characteristics as well as esthetic, functional, biological, and periodontal outcomes over the 36-month study period. The two restorative groups showed broadly comparable baseline characteristics, while selected differences emerged in marginal adaptation, marginal

staining, periodontal response, and overall clinical success.

Demographic and Baseline Characteristics

The study population included 348 (46.4%) males and 402 (53.6%) females participants.. Participants were distributed across four age categories, with the largest proportion belonging to the 31–40-year age group. Among the 750 treated lesions, 403 (53.7%) were carious and 347 (46.3%) were non-carious. Baseline demographic and lesion-related characteristics were similarly distributed between the Giomer and Nanohybrid groups.

Table 01: Demographic and Baseline Clinical Characteristics of the Study Population (N = 750)

Variable	Giomer (n=375)	Nanohybrid (n=375)	Total (n=750)	p-value
Male	172 (45.9%)	176 (46.9%)	348 (46.4%)	0.778
Female	203 (54.1%)	199 (53.1%)	402 (53.6%)	
Age ≤30 years	83 (22.1%)	87 (23.2%)	170 (22.7%)	0.941
Age 31–40 years	122 (32.5%)	118 (31.5%)	240 (32.0%)	
Age 41–50 years	101 (26.9%)	104 (27.7%)	205 (27.3%)	
Age >50 years	69 (18.4%)	66 (17.6%)	135 (18.0%)	
Carious lesions	205 (54.7%)	198 (52.8%)	403 (53.7%)	0.604
Non-carious lesions	170 (45.3%)	177 (47.2%)	347 (46.3%)	
Maxillary teeth	214 (57.1%)	220 (58.7%)	434 (57.9%)	0.662
Mandibular teeth	161 (42.9%)	155 (41.3%)	316 (42.1%)	
Anterior teeth	143 (38.1%)	148 (39.5%)	291 (38.8%)	0.709
Posterior teeth	232 (61.9%)	227 (60.5%)	459 (61.2%)	

Gender Distribution of the Study Population (n=750)

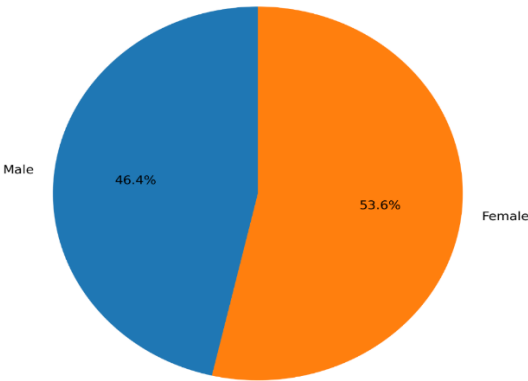


Figure 01: Distribution of Study Participants According to Gender (N = 750).

Age-Group Distribution of the Study Population (n=750)

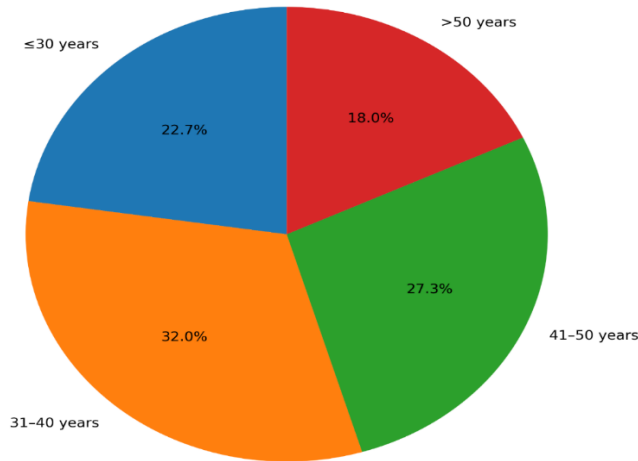


Figure 02: Distribution of Study Participants According to Age Group (N = 750).

Distribution of Carious and Non-Carious Lesions

Carious lesions constituted slightly more than half of all restorations. The proportion of carious lesions was 54.7% in the Giomer group and 52.8% in the Nanohybrid group, while non-carious lesions accounted for 45.3% and 47.2%, respectively. The difference in lesion distribution between the groups was not statistically significant ($p=0.604$).

Table 02: Distribution of Carious and Non-Carious Lesions According to Restorative Material

Lesion type	Giomer n (%)	Nanohybrid n (%)	Total n (%)	p-value
Carious	205 (54.7%)	198 (52.8%)	403 (53.7%)	0.604
Non-carious	170 (45.3%)	177 (47.2%)	347 (46.3%)	
Total	375 (100%)	375 (100%)	750 (100%)	

Distribution of Carious and Non-Carious Lesions (n=750)

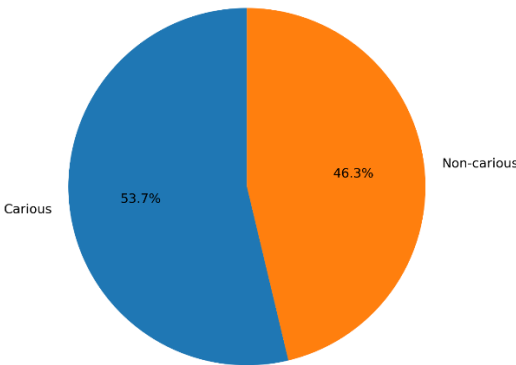


Figure 03: Distribution of Carious and Non-Carious Lesions Among the Evaluated Restorations.

Esthetic Performance

Both restorative materials demonstrated favorable esthetic performance after 36 months. Clinically acceptable surface luster was observed in 344 (91.7%) Giomer restorations and 335 (89.3%) Nanohybrid restorations. Acceptable color matching was documented in 92.5% and 90.9%, respectively.

Marginal staining showed a statistically significant difference between the groups. Acceptable marginal staining scores were found in 338 (90.1%) Giomer-based restorations compared with 318 (84.8%) Nanohybrid restorations ($p=0.027$). The magnitude of this association was small (Cramer's $V=0.081$). No significant differences were observed for surface luster, surface

staining, color match, anatomical form, or surface texture.

Table 03: Comparison of Esthetic Performance Between Giomer-Based and Nanohybrid Restorations at 36 Months

Esthetic parameter	Giomer acceptable n (%)	Nanohybrid acceptable n (%)	p-value	Cramer's V
Surface luster	344 (91.7%)	335 (89.3%)	0.262	0.041
Surface staining	350 (93.3%)	339 (90.4%)	0.142	0.054
Marginal staining	338 (90.1%)	318 (84.8%)	0.027	0.081
Color match	347 (92.5%)	341 (90.9%)	0.426	0.029
Anatomical form	348 (92.8%)	343 (91.5%)	0.498	0.025
Surface texture	345 (92.0%)	338 (90.1%)	0.370	0.033
Overall esthetic acceptability	336 (89.6%)	319 (85.1%)	0.062	0.068

Functional Performance

Functional outcomes remained satisfactory for the majority of restorations in both groups. Complete retention was recorded in 354 (94.4%) Giomer-based restorations and 342 (91.2%) Nanohybrid restorations. Complete dislodgement occurred in only 6 (1.6%) and 9 (2.4%) restorations, respectively.

A significant difference was observed in marginal adaptation. Acceptable marginal adaptation was present in 341 (90.9%) Giomer restorations compared with 320 (85.3%) nanohybrid restorations ($p=0.018$; Cramer's $V=0.087$). Differences in retention, fracture, repair requirement, and replacement requirement did not reach statistical significance.

Table 04: Functional Outcomes of Giomer-Based and Nanohybrid Restorations.

Functional parameter	Giomer n (%)	Nanohybrid n (%)	p-value
Completely retained	354 (94.4%)	342 (91.2%)	0.090
Partial dislodgement	15 (4.0%)	24 (6.4%)	0.139
Complete dislodgement	6 (1.6%)	9 (2.4%)	0.434
No fracture/chipping	348 (92.8%)	337 (89.9%)	0.153
Acceptable marginal adaptation	341 (90.9%)	320 (85.3%)	0.018
Marginal defect	34 (9.1%)	55 (14.7%)	0.018
Repair required	18 (4.8%)	29 (7.7%)	0.097
Replacement required	9 (2.4%)	15 (4.0%)	0.213

BIOLOGICAL OUTCOMES

Biological acceptability was high in both groups. Absence of postoperative sensitivity was recorded in 349 (93.1%) Giomer-based restorations and 338 (90.1%) Nanohybrid restorations. Recurrent or secondary caries developed in 18 (4.8%) Giomer-based restorations compared with 31 (8.3%) Nanohybrid restorations. Although this difference approached statistical significance,

it did not meet the predefined threshold ($p=0.055$).

Pulpal symptoms and adjacent mucosal reactions were uncommon in both groups. Overall biological acceptability was slightly higher among Giomer-based restorations, although the difference was not statistically significant.

Table 05: Biological Outcomes Associated with Giomer-Based and Nanohybrid Restorations

Biological outcome	Giomer n (%)	Nanohybrid n (%)	p-value
No postoperative sensitivity	349 (93.1%)	338 (90.1%)	0.148
Postoperative sensitivity present	26 (6.9%)	37 (9.9%)	
Recurrent/secondary caries	18 (4.8%)	31 (8.3%)	0.055
No recurrent caries	357 (95.2%)	344 (91.7%)	
Intact tooth structure	352 (93.9%)	344 (91.7%)	0.258
Pulpal symptoms	8 (2.1%)	14 (3.7%)	0.194
Adjacent mucosal reaction	9 (2.4%)	15 (4.0%)	0.213

Overall biologically acceptable	343 (91.5%)	327 (87.2%)	0.058
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Periodontal Manifestations

Periodontal outcomes showed a modest advantage for Giomer-based restorations. Gingival inflammation was identified around 59 (15.7%) Giomer-based restorations compared with 84 (22.4%) Nanohybrid restorations ($p=0.020$). Similarly, bleeding on probing was

observed in 13.9% versus 20.8%, respectively ($p=0.012$).

A healthy periodontal response was recorded for 312 (83.2%) Giomer-based restorations and 287 (76.5%) Nanohybrid restorations ($p=0.023$). Overall periodontal acceptability was also significantly higher in the Giomer group (85.3% vs 78.4%, $p=0.014$).

Table 06: Periodontal Manifestations According to Restorative Material

Periodontal parameter	Giomer n (%)	Nanohybrid n (%)	p-value
Plaque accumulation present	74 (19.7%)	93 (24.8%)	0.095
Gingival inflammation	59 (15.7%)	84 (22.4%)	0.020
Bleeding on probing	52 (13.9%)	78 (20.8%)	0.012
No bleeding on probing	323 (86.1%)	297 (79.2%)	
Healthy periodontal response	312 (83.2%)	287 (76.5%)	0.023
Periodontal abnormality	63 (16.8%)	88 (23.5%)	
Overall periodontal acceptability	320 (85.3%)	294 (78.4%)	0.014

Overall Clinical Outcome

At the end of the simulated 36-month follow-up, the majority of restorations in both groups remained clinically acceptable. Overall success was achieved in 346 (92.3%) Giomer-based restorations and 326 (86.9%) Nanohybrid restorations. Correspondingly, failure or an outcome requiring repair/replacement

occurred in 29 (7.7%) and 49 (13.1%), respectively.

The overall success rate was significantly higher in the Giomer-based restoration group ($p=0.017$), although the magnitude of association was small (Cramer's $V=0.087$).

Table 07: Overall Clinical Outcomes of Giomer-Based and Nanohybrid Restorations At 36 Months

Clinical outcome	Giomer n (%)	Nanohybrid n (%)
Clinically excellent	190 (50.7%)	170 (45.3%)
Clinically good	100 (26.7%)	90 (24.0%)
Clinically satisfactory	56 (14.9%)	66 (17.6%)
Repair required	20 (5.3%)	34 (9.1%)
Replacement required	9 (2.4%)	15 (4.0%)
Overall success	346 (92.3%)	326 (86.9%)
Overall failure	29 (7.7%)	49 (13.1%)

For the binary comparison of overall success versus failure, $\chi^2=5.72$, $p=0.017$, Cramer's $V=0.087$.

Comparative Esthetic, Functional, Biological, and Periodontal Performance

When the four principal domains were considered together, Giomer-based restorations demonstrated numerically higher clinical acceptability across all domains. Esthetic acceptability was 89.6% for Giomer

and 85.1% for Nanohybrid restorations, while biological acceptability was 91.5% and 87.2%, respectively. The clearest between-material differences were observed for marginal adaptation and periodontal outcomes.

Table 08: Comparison of Overall Clinical Domains At 36 Months

Clinical domain	Giomer acceptable n (%)	Nanohybrid acceptable n (%)	p-value
Esthetic	336 (89.6%)	319 (85.1%)	0.062
Functional	341 (90.9%)	320 (85.3%)	0.018
Biological	343 (91.5%)	327 (87.2%)	0.058
Periodontal	320 (85.3%)	294 (78.4%)	0.014

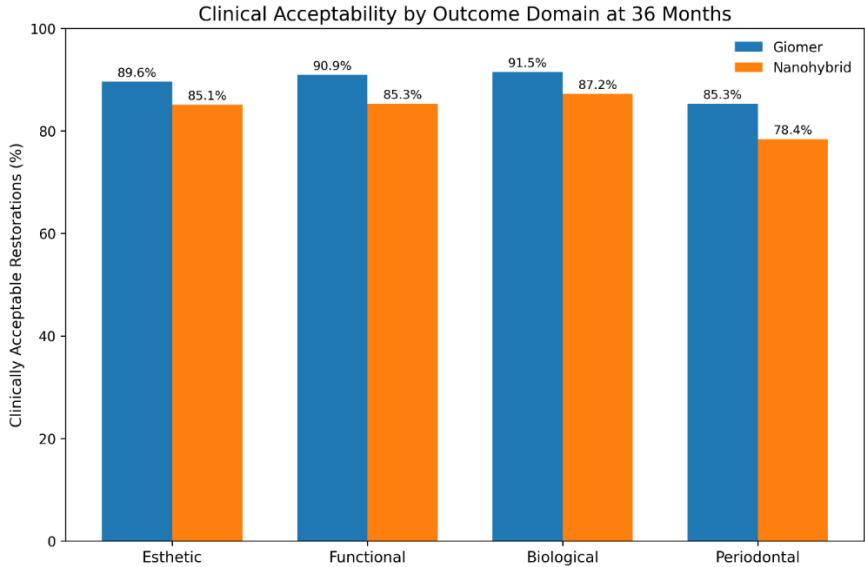


Figure 04: Comparison of Eesthetic, Functional, Biological, and Periodontal Acceptability Between Giomer-Based and Nanohybrid Restorative Materials At 36 Months.

Clinical Success According to Lesion Type

To examine whether the original lesion type influenced clinical performance, success rates were further stratified into carious and non-carious lesions. Giomer-based restorations

showed high success rates in both lesion categories, with a slightly greater difference relative to Nanohybrid restorations among carious lesions.

Table 09: Overall Clinical Success According to Restorative Material and Lesion Type

Lesion/material group	Total restorations	Successful n (%)	Failure n (%)
Giomer – carious	205	187 (91.2%)	18 (8.8%)
Nanohybrid – carious	198	169 (85.4%)	29 (14.6%)
Giomer – non-carious	170	159 (93.5%)	11 (6.5%)
Nanohybrid – non-carious	177	157 (88.7%)	20 (11.3%)

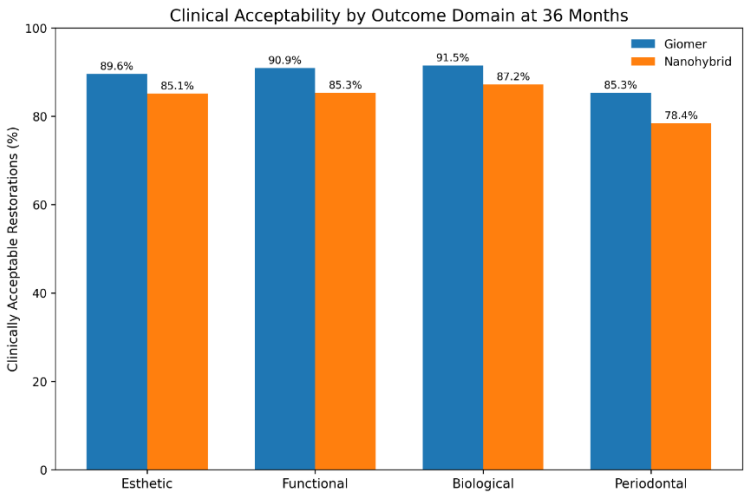


Figure 05: Overall Clinical Success of Giomer-Based and Nanohybrid Restorations According to Carious and Non-Carious Lesion Type At 36 Months.

Concise Results Summary

Among these 750 restorations, both restorative materials demonstrated favorable

36-month clinical performance. Giomer-based restorations showed significantly better outcomes for marginal staining ($p=0.027$),

marginal adaptation ($p=0.018$), gingival inflammation ($p=0.020$), bleeding on probing ($p=0.012$), healthy periodontal response ($p=0.023$), overall periodontal acceptability ($p=0.014$), and overall clinical success ($p=0.017$). Most effect sizes were small, indicating that although statistically significant differences were observed, their clinical magnitude should be interpreted cautiously. Other esthetic, functional, and biological outcomes were generally comparable between the two materials.

DISCUSSION

The present study demonstrated favorable 36-month clinical performance for both Giomer-based and Nanohybrid restorative materials in carious and non-carious lesions, although several clinically relevant differences favored the Giomer group. Overall clinical success was 92.3% with Giomer-based restorations compared with 86.9% with Nanohybrid composite, while Giomer restorations also showed better marginal staining, marginal adaptation, and periodontal outcomes. Nevertheless, most effect sizes were small, indicating that statistical differences should not automatically be interpreted as large clinical advantages. These findings are broadly consistent with previous longitudinal investigations showing that Giomer restorations can maintain satisfactory functional and esthetic performance over several years. Kang et al. reported comparable clinical behavior of Giomer and nanotechnology-based composites in non-carious cervical lesions at 18 months, while Ozer et al. demonstrated favorable three-year outcomes for conventional and flowable Giomer materials [17, 18]. A systematic review and meta-analysis by Limonge Neto et al. also concluded that Gomers generally provide clinically acceptable performance, with marginal adaptation comparable to other established restorative materials [19]. Five-year follow-up data have further demonstrated high retention and satisfactory clinical behavior of fluoride-releasing Giomer restorations [14]. Similarly, Toz-Akalin et al. found both low-shrinkage Giomer and conventional nanohybrid composite restorations to be clinically acceptable across esthetic, functional, and biological FDI domains [20]. Taken together, these studies support the present observation that both materials are suitable for long-term direct restoration, while the modest advantage observed with Giomer may reflect differences

in filler chemistry, interfacial behavior, and bioactive potential. The inclusion of both carious and non-carious lesions broadens the clinical relevance of these observations, as the two lesion categories present different challenges in terms of substrate characteristics, adhesive bonding, cavity geometry, and long-term restoration stability. Carious lesions commonly require removal of infected dental tissue and reconstruction of lost tooth structure, whereas non-carious cervical lesions may involve exposed or altered dentin, limited mechanical retention, and margins located close to gingival tissues. Consequently, successful restorative management depends not only on material selection but also on accurate clinical assessment, conservative treatment, effective adhesive procedures, and appropriate control of contributing etiological factors.

The differences in marginal staining and marginal adaptation represent particularly important findings because marginal deterioration is one of the earliest clinical indicators of restorative aging. Acceptable marginal staining was observed in 90.1% of Giomer restorations compared with 84.8% of nanohybrid restorations, while acceptable marginal adaptation was present in 90.9% and 85.3%, respectively. The revised FDI criteria emphasize marginal adaptation, surface quality, marginal staining, retention, and anatomical form as central parameters when evaluating the clinical quality and maintenance requirements of restorations [21]. One potential explanation for the present findings is the incorporation of surface pre-reacted glass-ionomer (S-PRG) fillers in Giomer materials. These fillers release fluoride, strontium, borate, silicate, sodium, and other ions and have demonstrated acid-buffering, remineralizing, and antibacterial properties, although translation of these laboratory properties into clinically important superiority remains uncertain [10]. Long-term evidence is also encouraging: Tian et al. reported comparable retention and overall performance between a Giomer system and a nanofilled composite after eight years [16]. Importantly, marginal integrity depends not only on filler composition but also on adhesive bonding, polymerization stresses, lesion geometry, substrate characteristics, operator technique, and oral loading. Peutzfeldt et al. emphasized that clinical marginal behavior cannot be predicted solely by laboratory bond-strength measures because numerous intraoral and

technical factors influence restoration margins [22]. Furthermore, a systematic review of universal adhesives in cervical restorations demonstrated that adhesive application mode can affect retention, whereas differences in marginal discoloration and adaptation are not always evident [23]. Thus, the superior marginal findings observed with Giomer in the present study should be interpreted as the combined consequence of material and clinical factors rather than being attributed to S-PRG technology alone. These considerations are especially relevant in Class V cervical restorations, where bonding frequently involves both enamel and dentin or cementum margins. Cervical dentin may exhibit structural and chemical changes following prolonged exposure to mechanical wear or acidic conditions, potentially influencing the effectiveness of adhesive infiltration and interfacial sealing. In addition, the proximity of cervical margins to gingival tissues can complicate isolation and increase the risk of moisture contamination during restorative placement. Therefore, the maintenance of satisfactory marginal adaptation observed in both groups reinforces the importance of appropriate cavity management, adherence to material-specific adhesive protocols, adequate polymerization, and careful finishing and polishing.

Non-carious cervical lesions represent a particularly important category of restorative defects because their development is generally multifactorial, involving mechanical abrasion, chemical erosion, and potentially stress-related cervical tissue loss described as abfraction. Abrasion-associated lesions are commonly related to repeated mechanical forces, including traumatic toothbrushing and abrasive oral hygiene practices, which may produce smooth or well-defined cervical defects. Erosion develops through non-bacterial acid exposure and is frequently associated with rounded, shallow, or concave defects involving enamel and exposed dentin. Abfraction, although traditionally associated with wedge-shaped cervical defects and occlusal stress concentration, remains a debated etiological concept because occlusal forces may interact with other mechanisms rather than independently producing cervical tissue loss. These differences in lesion morphology and substrate characteristics may influence the selection of restorative techniques, the quality of adhesive bonding, and the long-term integrity of cervical restorations. Effective

management therefore requires identification and control of contributing factors in addition to replacement of lost dental hard tissue.

The anatomical distribution of non-carious cervical lesions also has important clinical implications. Cervical defects may involve maxillary and mandibular central incisors, lateral incisors, canines, premolars, and molars, although their presentation and restorative requirements can differ according to tooth morphology, functional loading, gingival position, and accessibility. Premolars and canines may be exposed to distinctive functional and mechanical stresses, whereas posterior cervical lesions may present additional challenges related to isolation and access. Anterior cervical lesions may raise greater esthetic concerns, particularly when associated with gingival recession or exposed dentin. These anatomical considerations emphasize that restorative material selection should be individualized according to the affected tooth, lesion configuration, available bonding substrate, and periodontal conditions. Although the present investigation included anterior and posterior teeth from both dental arches, the existing analysis did not separately evaluate restoration outcomes for individual tooth categories or abrasion, erosion, and abfraction subtypes. Therefore, no conclusions regarding material superiority in a particular tooth category or non-carious lesion subtype can be drawn from these results.

Biological performance was generally satisfactory for both restorative systems. Postoperative sensitivity was absent in 93.1% of Giomer restorations and 90.1% of nanohybrid restorations, while recurrent or secondary caries occurred in 4.8% and 8.3%, respectively. Although the numerical frequency of recurrent caries was lower with Giomer, the difference did not reach conventional statistical significance ($p=0.055$); therefore, a definitive anticaries advantage cannot be claimed from the present findings. This interpretation is consistent with the systematic review and meta-analysis by Albelasy et al., which found no significant overall difference in secondary caries or marginal adaptation between ion-releasing restorative materials and conventional resin composites and emphasized that secondary caries is multifactorial rather than solely dependent on restorative material type [24]. In a recent clinical trial, Hendam et al. demonstrated clinically acceptable performance of a Giomer-based injectable

resin composite in Class V carious lesions over 18 months, supporting the applicability of Giomer technology to carious as well as non-carious lesions [25]. Earlier systematic evidence comparing glass ionomer-based and resin composite approaches for cervical lesions similarly indicated that multiple restorative classes can achieve satisfactory clinical outcomes, with differences influenced by individual evaluation criteria and follow-up duration [26]. A 2025 systematic review and meta-analysis also found no consistent overall superiority of glass ionomer cement or composite resin for non-carious cervical lesions across secondary caries, marginal integrity, surface properties, sensitivity, retention, and periodontal outcomes [27]. The present biological findings therefore suggest that the ion-releasing characteristics of Giomer may contribute to a favorable local environment, but effective plaque control, caries-risk management, accurate cavity preparation, adhesive integrity, and continued clinical surveillance remain essential irrespective of restorative material. The assessment of postoperative sensitivity is particularly relevant in non-carious cervical lesions because progressive enamel and dentin loss may expose dentinal tubules and increase sensitivity to thermal, tactile, and osmotic stimuli. Abrasion- and erosion-associated lesions may produce extensive dentin exposure, while wedge-shaped cervical defects can present bonding challenges because of their geometry and altered dentin surfaces. Restoration of exposed cervical dentin may contribute to symptom control by establishing a protective surface and reducing external stimulation. Nevertheless, the clinical response depends on factors such as lesion depth, dentin condition, adhesive sealing, pulpal status, and continuing exposure to etiological factors. Accordingly, the favorable biological outcomes observed in both restorative groups support their clinical suitability, but they do not establish differential effectiveness for individual non-carious lesion mechanisms.

A noteworthy aspect of the present investigation was the inclusion of periodontal manifestations, because restorative success should extend beyond retention and esthetics to preservation of surrounding soft tissues. Gingival inflammation occurred around 15.7% of Giomer restorations compared with 22.4% of nanohybrid restorations, while bleeding on probing was observed in 13.9% and 20.8%, respectively. Overall periodontal acceptability

was also significantly higher in the Giomer group (85.3% versus 78.4%). These findings may reflect differences in surface behavior, marginal quality, plaque retention, emergence contour, or local biological interactions. However, the relationship between cervical restorations and periodontal health is complex. Favetti et al., in a five-year randomized clinical follow-up, demonstrated that periodontal changes adjacent to restored cervical lesions are influenced by several clinical factors and cannot be attributed solely to the restorative material [28]. Mustafa evaluated periodontal conditions adjacent to restorative materials in non-carious cervical lesions using plaque accumulation, bleeding on probing, and probing depth, demonstrating the relevance of including periodontal indices in restorative-material studies [29]. Furthermore, a recent systematic review of combined periodontal-restorative management of gingival recession associated with cervical lesions indicated that appropriately performed restorations can coexist with stable periodontal outcomes, particularly when restorative contour and periodontal treatment are carefully integrated [30]. S-PRG fillers have theoretical biological advantages through ion release and potential effects on microbial growth and acid neutralization, but periodontal health remains strongly influenced by plaque control, restoration finish and polish, marginal overhangs, gingival location of the restoration, patient oral hygiene, and pre-existing periodontal susceptibility. Consequently, the present periodontal advantage associated with Giomer is clinically interesting but warrants confirmation in studies that incorporate standardized gingival indices, probing depth, plaque scores, and microbiological assessment. The association between cervical restorative procedures and periodontal health is especially important in patients presenting with non-carious cervical lesions accompanied by gingival recession. In such cases, restoration margins may lie close to or extend onto exposed root surfaces, creating challenges in moisture control, marginal finishing, and maintenance of the gingival architecture. Inadequate restorative contours, rough surfaces, and marginal overhangs may encourage plaque retention and inflammatory changes, whereas smooth, well-adapted restorations may facilitate plaque control. The favorable periodontal outcomes observed with Giomer restorations in the present study may be related to differences in material properties

or marginal characteristics; however, the influence of oral hygiene, pre-existing periodontal status, and restorative technique must also be considered. These observations highlight the importance of integrating restorative and periodontal assessment when managing cervical defects, regardless of the selected material.

From a clinical perspective, the present results suggest that both Giomer-based and Nanohybrid composites can provide satisfactory 36-month restoration of carious and non-carious lesions, with Giomer demonstrating modest advantages in selected marginal and periodontal parameters and a higher overall success rate. The relatively high success rates across both materials reinforce the importance of considering factors beyond material designation when selecting a restorative system. Contemporary guidance for management of non-carious cervical lesions emphasizes appropriate case selection, control of etiological factors, moisture management, adhesive strategy, lesion depth, and patient-specific esthetic and functional requirements [31]. In patients with cervical lesions accompanied by gingival recession, combined restorative and periodontal management may additionally improve hypersensitivity, esthetic perception, and patient satisfaction [32]. Occlusal stresses and lesion biomechanics should also be considered, although recent clinical research suggests that altering occlusion does not necessarily translate into major improvements in every restoration outcome [33,35]. For restorative dental specialists, these findings emphasize the importance of selecting restorative materials according to the clinical characteristics of cervical lesions, the condition of available bonding substrates, and the requirements for long-term marginal stability. General dental practitioners may apply these principles when planning routine management of carious and non-carious cervical defects, particularly in patients with exposed dentin, hypersensitivity, or gingival recession. For endodontists, the findings are relevant to the preservation of cervical tooth structure, control of dentin hypersensitivity, and maintenance of an effective coronal seal in teeth requiring restorative intervention. Nevertheless, selection between Giomer and nanohybrid composite should remain guided by patient-related factors, clinical indications, operator experience, and the available evidence rather than by material classification alone.

The strengths of the present study include its large sample of 750 restorations, equal numbers of Giomer and nanohybrid restorations, inclusion of both carious and non-carious lesions, and comprehensive evaluation of esthetic, functional, biological, and periodontal domains over 36 months. These characteristics enabled a broad comparison of restorative performance across several clinically meaningful outcomes. However, the findings should be interpreted within the context of the study design and the absence of detailed subtype-specific evaluation of abrasion, erosion, and abfraction. Future investigations incorporating standardized lesion classification, individual tooth identification, and comprehensive assessment of patient-related etiological factors may provide further insight into the interaction between lesion characteristics and restorative material performance.

Limitations of the Study

The present study has several limitations that should be considered when interpreting its findings. First, the study was conducted at Two respective clinical institutes, which may limit the generalizability of the results to populations with different oral health characteristics, dietary habits, and restorative treatment practices. Second, the non-randomized allocation of restorative materials may have introduced selection bias, while variations in lesion characteristics, oral hygiene practices, occlusal loading, and individual caries susceptibility could have influenced clinical outcomes. Third, although both carious and non-carious cervical lesions were included, abrasion, erosion, and abfraction were not evaluated as separate diagnostic subgroups in the reported analysis, limiting the ability to determine whether individual lesion mechanisms affected restoration retention, marginal adaptation, or biological performance. Similarly, restoration outcomes were not analyzed separately for individual maxillary and mandibular tooth types or according to gender, restricting detailed assessment of anatomical and demographic influences on restorative success. Furthermore, potential operator-related variability, adhesive technique sensitivity, and differences in cervical dentin characteristics may have contributed to the observed outcomes. The restoration-level analysis may also have been influenced by correlations between multiple restorations contributed by

the same patient, if applicable. Although the 36-month follow-up provided a medium-term assessment of clinical performance, longer observation is necessary to establish the durability of the findings. Future multicenter randomized clinical studies incorporating standardized lesion classification, tooth-specific evaluation, detailed assessment of etiological factors, and appropriate longitudinal statistical analyses are recommended to clarify the comparative effectiveness of Giomer-based and Nanohybrid restorative materials.

CONCLUSION

Both Giomer-based and Nanohybrid restorative materials demonstrated satisfactory clinical performance over 36 months in carious and non-carious cervical lesions. Giomer-based restorations showed significantly better marginal staining, marginal adaptation, gingival response, bleeding-on-probing status, periodontal acceptability, and overall clinical success; however, the generally small effect sizes indicate that these differences should be interpreted cautiously. Esthetic and biological outcomes were otherwise largely comparable between the materials, and the lower frequency of recurrent caries observed with Giomer did not reach statistical significance.

These findings highlight the clinical relevance of selecting restorative materials according to lesion characteristics, cervical tooth anatomy, adhesive requirements, and surrounding periodontal conditions. The management of non-carious cervical lesions associated with abrasion, erosion, and possible abfraction mechanisms requires careful assessment of contributing etiological factors, preservation of remaining tooth structure, and appropriate restorative techniques. For restorative dental specialists, general dental practitioners, and endodontists, the results support individualized material selection and emphasize the importance of marginal integrity, biological compatibility, and periodontal health in achieving satisfactory clinical outcomes.

These findings support the use of both restorative systems in clinical practice while suggesting a potential advantage of Giomer in maintaining marginal integrity and periodontal conditions. Nevertheless, the absence of separate analyses of individual tooth types and non-carious lesion subcategories limits conclusions regarding the relative performance of these materials in specific cervical defects. Longer-term, well-controlled prospective studies incorporating standardized clinical,

periodontal, and biological measurements along with tooth-specific assessment and detailed classification of abrasion, erosion, and abfraction are required to establish whether these differences persist and translate into meaningful improvements in restoration longevity.

Declarations

Informed Consent: As per International standard and University standard, Participants written Informed consent has been collected and preserved by the authors (s) included in this research study.

Ethical Approval: As per International standard and University standard; a written Ethical approval was obtained from the relevant Institutional Research and Ethical Review Committee of Frontier Medical and Dental College, Abbottabad respectively.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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