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Asian Journal of Dental and Health Sciences

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To evaluate the improvement of the mechanical property of three different GIC's combined with 2% Graphene Oxide using the 2-point bend test: an in-vitro study

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Article Info:

Article History:

Received 11 Nov 2025
Reviewed 02 Jan 2026
Accepted 24 Jan 2026
Published 15 March 2026

Cite this article as:

Gupta V, Nagpal R, Heda A, Khandelwal A, Parkale P, Agrawal K, To evaluate the improvement of the mechanical property of three different GIC's combined with 2% Graphene Oxide using the 2-point bend test: an in-vitro study, Asian Journal of Dental and Health Sciences. 2026; 6(1):5-8 *DOI: http://dx.doi.org/10.22270/ajdhs.v6i1.152*

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Abstract

Objective: Glass ionomer systems are widely used in dentistry for their multifarious advantages, such as chemical adhesion, fluoride release, and biocompatibility. However, its low flexural strength and brittleness limit its clinical outcome. Graphene oxide, a nanofiller has shown promising results with increased mechanical and physiochemical properties. This case report examines the improvement of flexural strength of four different restorative GIC's combined with 2% Graphene Oxide using two- point bend test.

Materials and Methods: Experimental modified GIC's were prepared by adding 2% graphene oxide with three different traditional GIC's using measuring scale. Mechanical mixing was carried out and three different specimens were prepared in a silicone mould. Flexural strength of each experimental and control group was investigated using a two- point bend test.

Results: Graphene Oxide mixed with GIC shows higher flexural strength as compared to conventional GIC.

Significance: Adding Graphene oxide to GIC can significantly improve its mechanical properties, providing clinical benefits. In addition, it does not affect the solubility or fluoride-ion-releasing properties of the material, which opens new avenues for restorative dentistry.

Keywords: Glass Ionomer Cement, Graphene Oxide, flexural strength

1. Introduction:

Preservation of healthy set of natural teeth is of utmost importance to dental clinician. Over the past decades many revolutions have taken place to preserve the natural form and function of the teeth. One such revolution done by Wilson and Kent in 1972, was invention of tooth-colored restorative material, Glass Ionomer Cement (GIC). GIC, occupies a distinctive position in restorative dentistry due to its multifunctional advantages such as chemical adhesion to tooth structure, sustained fluoride release biocompatibility, and thermal compatibility with natural teeth. Their ability to chemically bond with both enamel and dentin via ionic interaction has made them valuable for restorative procedures that emphasize long-term seal integrity and minimal invasiveness.[1]

Despite these clinical benefits, GIC's are limited by their inherent brittleness, low tensile and flexural strength, and poor wear resistance, restricting their use in high-stress areas. The microstructure of conventional GIC involves a brittle glass matrix with limited cross-linking within the polyacrylate network, making it prone to microcrack formation under masticatory stress. Numerous modifications have been explored to enhance the mechanical properties of GICs, including resin reinforcement, incorporation of ceramic fillers, and the addition of nanomaterials. However, most of these approaches have compromised other essential properties, such as biocompatibility, fluoride release, and translucency.

Recent advancements in nanotechnology have introduced promising materials that can address these challenges. Among these, graphene oxide (GO) has emerged as an exceptional nanomaterial due to its remarkable mechanical strength, large surface area, and functional oxygen-containing groups.[2] GO exhibits active interfacial bonding with polymeric and inorganic matrices, allowing effective stress transfer and improved structural reinforcement. When incorporated into dental materials, GO can enhance mechanical durability, wear resistance, and elasticity while maintaining or even improving the material's biofunctional attributes. Several experimental studies have reported the beneficial influence of GO on dental composites, adhesives, and cements. Its incorporation into GIC has shown potential improvement in flexural and compressive strength, as well as enhanced resistance to fracture without adversely affecting translucency, handling characteristics, or fluoride release.

This study seeks to assess the mechanical reinforcement potential of GO and its applicability in enhancing the clinical performance of GIC restorations. Understanding and optimizing this modification could signify a major advancement toward developing next-generation restorative materials that combine mechanical resilience, chemical adhesion, and biological compatibility essential for long-term success in restorative dentistry.

2. Materials and Methods:

2.1: Sample Preparation:

Four commercial GIC were selected as base materials. Experimental groups were prepared by incorporating 2% graphene oxide (by weight) into each GIC using a precised measuring scale.

Group A: Conventional GIC samples.

Group A1: Ketac Molar, 3M.

Group A2: RX EASE GIC, Shofu.

Group A3: Type II restorative GIC, GC.

Group B: GIC combined with Graphene oxide.

Group B1: Ketac Molar, 3M incorporated with 2% graphene oxide.

Group B2: RX EASE GIC, Shofu, incorporated with 2% graphene oxide.

Group B3: Type II restorative GIC, GC incorporated with 2% graphene oxide.

2.2: Preparation of GIC samples:

The GIC was mechanically mixed with 2% (by weight) GO for 25 seconds to ensure homogeneity. The mixture was transferred to the mould. After the setting process, specimens were evaluated for flexural strength.

2.3: Flexural Strength Test:

The samples were tested for flexural strength using a three-point bend test on a universal testing machine at a crosshead speed of 1 mm/min. The mean flexural strength values of the experimental and control groups were compared and statistically analyzed. The flexural strength (σ) was calculated in megapascals (MPa) using the following equation:

$$F= PL/bd^2$$

where F is the maximum load (N), L is the length of the sample (mm), B is the width of the sample (mm), and d is the deflection (mm) corresponding to the load F.

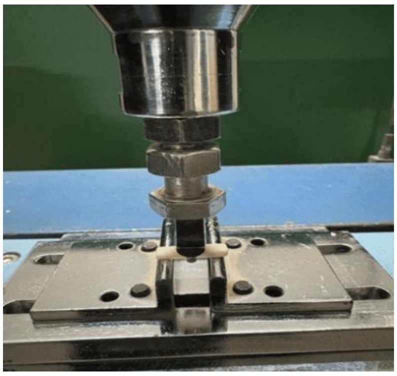

Figure 1: Two- point bend test

Group	Mean flexural strength	Standard Deviation
A1	5.20	1.17
A2	4.08	0.55
A3	4.40	1.01
B1	10.55	1.70
B2	6.35	1.41
B3	6.55	1.43

3. Statistical Analysis:

Data were analyzed using SPSS version 23 (SPSS Inc., IL, US). Two-way ANOVA analysis and posthoc Tukey test were used to show the effects of GIC type and GO percentage on flexural strength.

4. Results:

The experimental GICs containing 2% graphene oxide exhibited a significant increase in flexural strength compared to their respective control groups. The B1 group showed the highest flexural strength followed by B3 and B2. Group A2 exhibited lowest flexural strength. The improvement indicated an enhanced load-bearing capacity and reduced brittleness in the modified materials. No adverse effect on color, solubility, or fluoride release was observed, confirming the physicochemical compatibility of graphene oxide with GIC matrix systems.

5. Discussion:

The present study aimed to evaluate the effect of adding 2% graphene oxide (GO) on the flexural strength of three different restorative glass ionomer cements (GICs) using the standardized two-point bend test.[3] Two- point bend test is an extremely convenient technique for determining the strength and fatigue parameters of fibers in general and high strength optical fibers and ribbons in particular. The significant improvement in flexural strength observed in the experimental groups compared to the control groups indicates that graphene oxide possesses considerable potential as a reinforcing nanofiller for GICs. The results obtained are consistent with previous studies reporting enhanced mechanical and structural properties of dental restorative materials infused with graphene-based nanomaterials.[4]

The primary mechanism for the improvement in flexural strength is the unique structural characteristics of graphene oxide. GO consists of a single layer of carbon atoms arranged in a hexagonal lattice decorated with oxygen-containing functional groups such as hydroxyl, carboxyl, and epoxy groups. These functionalities promote strong interfacial bonding between the GO sheets and the polyacrylate chains of the GIC matrix. This interaction contributes to superior stress distribution and effective energy dissipation under loading conditions. Consequently, the propagation of microcracks is minimized, which enhances the overall load-bearing capacity of the material.[5]

The improved strength and toughness also stem from the nanoscale dispersion of GO particles within the glass ionomer matrix.[6] Even at a relatively low concentration of 2%, graphene oxide provides a network-like structure that bridges micro-voids and defects within the material. This interlocking effect restricts crack initiation and propagation, thereby increasing flexural resilience. Furthermore, mechanical mixing ensures homogeneous distribution of the nanofiller, leading to consistency across specimens.

Another advantage observed in this study is that the incorporation of 2% GO did not adversely affect critical parameters such as color stability, fluoride release, or solubility. This finding is particularly important from a clinical perspective, as maintaining the therapeutic benefits of GIC while simultaneously improving its mechanical performance is essential for long-term restorative success. The color neutrality of graphene oxide and its effective compatibility with inorganic glass particles ensure that the material remains aesthetically acceptable. The stable fluoride release pattern further indicates that GO reinforcement does not interfere with the acid-base reaction or the property of sustained ion exchange that characterizes conventional GICs.[7]

One limitation of traditional GICs is their brittleness, which often leads to marginal fractures or chipping in high-stress environments. The current findings suggest that graphene oxide reinforcement can reduce brittleness by enhancing flexibility and fracture toughness.[8] This characteristic is highly beneficial for clinical situations such as Class II restorations, core buildups, and atraumatic restorative procedures where durability under occlusal stress is crucial.

The results also align with the growing evidence that nanotechnology can revolutionize restorative material design. Graphene oxide stands out among other nanofillers, such as zirconia, alumina, and silica, due to its superior tensile modulus, biocompatibility, and ability to integrate into polymer networks. Its surface chemistry allows for functional modification, enabling further optimization of mechanical and antibacterial properties. In dentistry, GO-based composites are already being explored for endodontic sealers, adhesives, and implant coatings due to their multifunctional advantages, including antimicrobial action and bioactivity promotion.[9]

However, certain considerations must be addressed before extensive clinical application. The uniform dispersion of graphene oxide within the GIC matrix is crucial to prevent agglomeration, which could negatively impact optical transparency and handling properties.[10] Additionally, variations in GO synthesis, particle size, and functional group concentration can lead to differences in performance outcomes. Future studies should focus on standardizing preparation protocols, evaluating long-term stability, assessing wear resistance, and testing under cyclic loading conditions to simulate masticatory forces. Biocompatibility and cytotoxicity analyses are equally important to confirm the safety of GO-modified materials in direct contact with pulp or soft tissues.

Overall, this study's findings highlight the potential of graphene oxide as a promising reinforcement agent for conventional restorative glass ionomer cements. The observed improvements in flexural strength without compromising fluoride release, aesthetics, or solubility indicate a significant advancement toward the development of next-generation GICs. These enhanced materials could broaden clinical application in stress-bearing restorations and extend their functional lifespan, particularly in patients with high occlusal demands.

Conflict of Interest: The authors declare no potential conflict of interest concerning the contents, authorship, and/or publication of this article.

Author Contributions: All authors have equal contributions in the preparation of the manuscript and compilation.

Source of Support: Nil

Funding: The authors declared that this study has received no financial support.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Ethical approval: Not applicable.

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