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EVALUATION OF EFFECT OF NATURAL BIO-CALCIUM SOURCES AND COMMERCIAL REINFORCEMENTS ON THE COMPRESSIVE STRENGTH AND MICROHARDNESS OF GLASS IONOMER CEMENT – AN INVITRO STUDY

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ABSTRACT

Background: Glass ionomer cement (GIC) is widely used in restorative dentistry due to its fluoride release and chemical bonding to tooth structure, but its mechanical limitations restrict its use in high-stress bearing areas. Reinforcement with natural bio-calcium sources and commercial additives has been explored to enhance its performance. **Aim:** To evaluate and compare the compressive strength and microhardness of conventional GIC, GIC modified with chicken eggshell powder, GIC modified with seashell powder, Zirconomer, and Miracle Mix. **Materials and Methods:** One hundred specimens were prepared and randomly divided into five groups (n = 20 each): Group 1—Conventional GIC; Group 2—GIC + Chicken eggshell powder; Group 3—GIC + Seashell powder; Group 4—Zirconomer; Group 5—Miracle Mix. Each group was further subdivided into two subgroups (n = 10) for compressive strength and microhardness testing. Compressive strength was measured using a universal testing machine, and microhardness was assessed with a Vickers microhardness tester. Data were analyzed using one-way ANOVA and post hoc pairwise comparisons ($p < 0.05$). **Results:** Both natural bio-calcium additives (Groups 2 and 3) significantly improved compressive strength and microhardness compared to conventional GIC ($p < 0.05$). Zirconomer (Group 4) exhibited the highest values, followed closely by Miracle Mix (Group 5). Post hoc analysis confirmed significant differences between reinforced groups and the control, with no significant difference between Zirconomer and Miracle Mix ($p > 0.05$). **Conclusion:** Addition of natural bio-calcium sources such as eggshell and seashell powder enhances the mechanical properties of conventional GIC. However, commercial reinforcements, especially Zirconomer, remain superior. Bio-calcium modification represents a promising, cost-effective, and eco-friendly approach, but further long-term clinical studies are warranted.

KEYWORDS: Glass ionomer cement; Compressive strength; Microhardness; Eggshell powder; Seashell powder; Zirconomer; Miracle Mix.

INTRODUCTION

Glass ionomer cement (GIC) has been widely used in restorative dentistry since its introduction by Wilson and Kent in 1972, prized for properties such as chemical adhesion to mineralized tissues, biocompatibility, fluoride release, and a coefficient of thermal expansion similar to tooth structure.[1,2] Yet, conventional GIC remains limited by its relatively low mechanical strength and susceptibility to fracture under load-bearing conditions.[3]

To address these limitations, modifications of GIC have been explored—ranging from resin reinforcement to the incorporation of nanoparticles including alumina, hydroxyapatite, and fluoroapatite—without compromising fluoride release[3]. Among natural, sustainable alternatives, chicken eggshell powder (CESP)—predominantly calcium carbonate (~98%)—offers as an eco-friendly, cost-effective filler.[4,5]

Similarly, incorporation of seashell-derived calcium carbonate nanoparticles has enhanced the mechanical performance of GIC, particularly at higher concentrations.[6]

Commercial modifications such as Zirconomer (zirconia-reinforced GIC) and Miracle Mix (silver alloy-reinforced GIC) have also demonstrated superior strength compared with conventional GIC, with Zirconomer showing the highest values.[7,8]

Since compressive strength and microhardness are critical for the clinical durability of restorations, this in-vitro study compares conventional GIC (Type IX Extra), bio-calcium reinforced GICs (eggshell and seashell powder), and commercially reinforced GICs (Zirconomer and Miracle Mix) to evaluate their relative mechanical performance.

MATERIALS AND METHODS

Chicken eggshells and seashells were collected, cleaned, dried, calcined, and ground into fine powder using a ball mill, followed by sieving to obtain particle sizes <50 µm. These powders were incorporated into conventional GIC at 10 wt% concentration.

A total of **100 specimens** were prepared (n = 20 per group) : group 1(GIC Type IX extra, GC), group 2 (GIC Type IX extra ,GC + Chicken Egg Shell Powder), group 3 (GIC Type IX extra ,GC + Sea Shell Powder), group 4 (Zirconomer Improved, Shofu), and group 5 (Mircle Mix , GC). Of these, **10 specimens per group** were fabricated for compressive strength testing (cylinders, 3 × 6 mm) and **10 per group** for microhardness testing (discs, 6 × 2 mm), using stainless-steel molds. The test materials were manipulated as per the manufacturer's instructions and expressed slowly to prevent formation of voids into the mould coated with Vaseline until it was slightly overfilled. The excess material was removed and surface was smoothened using a Mylar strip. All specimens were stored in distilled water for 24 hours prior to testing. The materials were subjected to compressing testing in a Universal Testing Machine (Instron 3366) at a crosshead speed of 0.5mm/min. Vickers microhardness was measured using a microhardness tester with a 200 g load for 15 s. Three indentations per specimen were recorded, and mean values were used for analysis.

Data were analyzed with SPSS version XX (IBM Corp., USA). Normality was tested using the Shapiro–Wilk test. Intergroup comparisons were made with one-way ANOVA followed by Tukey's post hoc test. Statistical significance was set at $p < 0.05$.

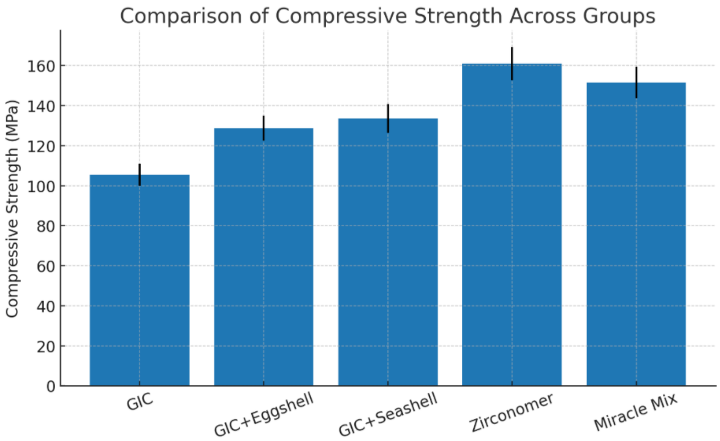
RESULTS

Compressive Strength

The mean compressive strength values (MPa) of all groups are summarized in **Table 1**. One-way ANOVA showed a statistically significant difference among the groups ($p < 0.05$). Tukey's post hoc analysis revealed that Zirconomer exhibited the highest compressive strength, followed closely by Miracle Mix, while conventional GIC showed the lowest values.

Table 1: Mean compressive strength (MPa) of study groups (n = 10 per group).

Group	Material	Mean ± SD (MPa)
1	Conventional GIC	105.4 ± 5.6
2	GIC + Eggshell Powder (CESP)	128.7 ± 6.2
3	GIC + Seashell Powder (SSP)	133.5 ± 7.1
4	Zirconomer	160.9 ± 8.3
5	Miracle Mix	151.5 ± 7.8

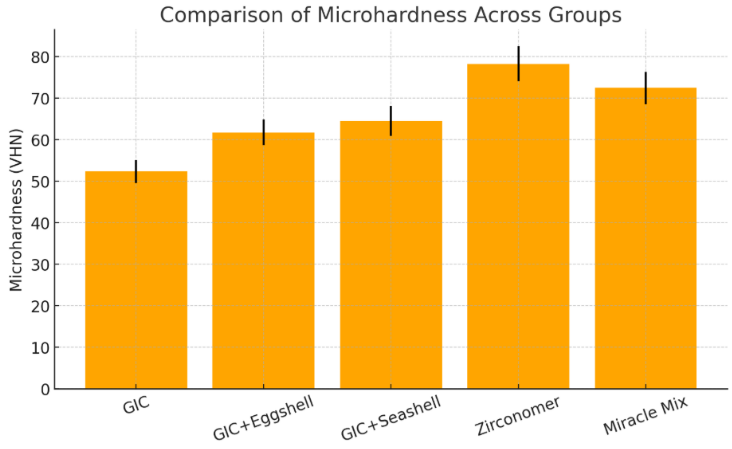


Microhardness

The mean Vickers microhardness values (VHN) are shown in **Table 2**. ANOVA demonstrated significant intergroup differences ($p < 0.05$). Tukey's post hoc test indicated that Zirconomer had the highest hardness, followed by Miracle Mix, while conventional GIC had the lowest. Both eggshell and seashell-modified GIC demonstrated improved hardness compared with unmodified GIC.

Table 2: Mean Vickers microhardness (VHN) of study groups (n = 10 per group).

Group	Material	Mean ± SD (VHN)
1	Conventional GIC	52.3 ± 2.8
2	GIC + Eggshell Powder (CESP)	61.7 ± 3.1
3	GIC + Seashell Powder (SSP)	64.5 ± 3.6
4	Zirconomer	78.2 ± 4.2
5	Miracle Mix	72.4 ± 3.9



DISCUSSION

The present in vitro study showed that both natural bio-calcium additives (eggshell and seashell powder) significantly improved the mechanical properties of conventional GIC. For compressive strength, Group 2 (GIC+Eggshell) and Group 3 (GIC+Seashell) demonstrated intermediate increases compared to unmodified GIC, whereas Zirconomer and Miracle Mix yielded the highest values. Similarly, microhardness was enhanced by natural additives, although Zirconomer again led the group, followed by Miracle Mix.

The strengthening effect of chicken eggshell powder on GIC aligns with previous findings. Allam and El-Geleel reported that the incorporation of 3–5 wt% eggshell powder significantly enhanced both compressive strength and microhardness relative to unmodified GIC, likely due to the high calcium carbonate content and particulate reinforcement within the matrix.[4] Seashell powder demonstrated a similar strengthening effect due to its comparable mineral composition.[9]

Zirconia-reinforced GIC (Zirconomer) showed significantly superior properties in this study. Prior research has confirmed that Zirconomer exhibits greater compressive and diametral tensile strength compared with conventional GIC ($p < 0.001$)[10,11], with reported values exceeding 180 MPa compared to ~118 MPa for Fuji IX.[12]

Miracle Mix, containing silver alloy particles, also outperformed conventional GIC, though slightly less than Zirconomer. Metal reinforcement has been shown to improve mechanical resilience of GIC at the expense of esthetics.[13]

Importantly, both eggshell- and seashell-modified GICs improved significantly over control groups, offering a sustainable, cost-effective alternative that avoids the aesthetic or environmental drawbacks associated with metal additives. Eggshell powder—composed mostly of calcium carbonate—provides a natural filler that reinforces the acid-base matrix and can participate in ion exchange, contributing additional benefits such as potential calcium and fluoride release.

The pairwise post hoc analysis underscored the significance of these differences: while bio-calcium groups were significantly stronger than control ($p < 0.05$), Zirconomer and Miracle Mix exhibited highly significant superiority ($p < 0.001$), with no significant difference between them ($p > 0.05$). These results support the notion that natural reinforcement may serve as a viable intermediate alternative when esthetics and cost are important considerations.

From a clinical viewpoint, enhancements in compressive strength and microhardness are meaningful because they directly correlate with resistance to occlusal loads and surface wear—key factors for longevity of restorations in posterior load-bearing areas. The improvements witnessed in groups with natural additives suggest potential for these materials in less demanding settings or as interim restorations.

However, some limitations must be acknowledged. This study assessed only short-term (24-hour) outcomes; long-term behavior under thermal/cyclic loading, ion release profile, and setting maturation were not explored and warrant further study. Moreover, further research into optimal wt% loading, particle size distribution, and possible effects on handling or setting kinetics would strengthen the evidence for clinical translation.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that incorporation of natural bio-calcium sources such as chicken eggshell and seashell powder significantly enhanced the compressive strength and microhardness of conventional GIC compared to the control. However, commercially reinforced cements, particularly Zirconomer, exhibited the highest mechanical performance, followed closely by Miracle Mix. Bio-calcium modification may provide a cost-effective and eco-friendly alternative for improving the properties of GIC, although long-term evaluations under clinical conditions are recommended before routine application.

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