

Comparative evaluation of protective coating agents on fracture resistance in zirconomer restorations: An in vitro study.

Vathsala N¹, M N Keerthana², Ashwija Shetty³, Keerthi Sagar NK⁴, Kruthi N Swamy⁵, Bhagavathi BC⁶

¹(Department of Conservative Dentistry and Endodontics, The Oxford Dental College, Bengaluru, Karnataka, India)

²(Department of Conservative Dentistry and Endodontics, The Oxford Dental College, Bengaluru, Karnataka, India)

³(Department of Conservative Dentistry and Endodontics, The Oxford Dental College, Bengaluru, Karnataka, India)

⁴(Department of Conservative Dentistry and Endodontics, The Oxford Dental College, Bengaluru, Karnataka, India)

⁵(Department of Conservative Dentistry and Endodontics, The Oxford Dental College, Bengaluru, Karnataka, India)

⁶(Department of Conservative Dentistry and Endodontics, The Oxford Dental College, Bengaluru, Karnataka, India)

Abstract:

Background: Zirconomer is a zirconia-reinforced glass ionomer restorative material with improved mechanical properties; however, its performance under occlusal loading may be influenced by the presence of surface defects and moisture-related degradation. Protective resin coatings have been reported to improve the surface integrity and mechanical properties of glass-ionomer-based restorative materials. This study aimed to evaluate and compare the fracture resistance of Zirconomer restorations coated with G-Coat Plus and Fusion Nano Coat following thermocycling.

Materials and Methods: Forty-five intact, non-carious maxillary first premolars extracted for orthodontic purposes were selected and randomly divided into three groups (n=15). Standardized Class I cavities were prepared using a 245 bur with a cavity depth of 2 mm and a width corresponding to one-third of the intercusp distance. Group I was restored with Zirconomer without a protective coating, Group II was restored with Zirconomer and coated with G-Coat Plus, and Group III was restored with Zirconomer and coated with Fusion Nano Coat. Following 24 hours of storage, all specimens underwent 500 thermocycles between 5°C and 55°C with a dwell time of 1 minute. Fracture resistance was evaluated using a universal testing machine with a 3-mm stainless-steel ball at a crosshead speed of 1 mm/min. Data were analyzed using Welch's analysis of variance followed by Games-Howell post hoc tests. Statistical significance was set at $p < 0.05$.

Results: The mean fracture resistance was 902.17 ± 10.03 N for Group I, 1176.18 ± 25.72 N for Group II, and 1022.30 ± 43.74 N for Group III. Welch's ANOVA demonstrated a statistically significant difference among the three groups ($F=742.56$, $p < 0.001$). Games-Howell post hoc analysis revealed significantly higher fracture resistance for Group II compared with Groups I and III, and significantly higher fracture resistance for Group III compared with Group I ($p < 0.001$ for all comparisons).

Conclusion: Within the limitations of this in vitro study, application of protective resin coatings significantly increased the fracture resistance of Class I Zirconomer restorations following thermocycling. G-Coat Plus demonstrated the highest fracture resistance, followed by Fusion Nano Coat, while uncoated Zirconomer showed the lowest values.

Key Word: Zirconomer; fracture resistance; G-Coat Plus; Fusion Nano Coat; protective coating; glass ionomer cement; thermocycling.

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I. Introduction

Cavity preparation compromises tooth structure and may reduce the fracture resistance of restored teeth.^{1,2} Glass ionomer cements have demonstrated limitations in fracture toughness and resistance to functional

loading.^{3,4} Zirconia-reinforced glass ionomer cement (Zirconomer) was developed to provide improved mechanical properties while retaining the beneficial characteristics of glass ionomer materials.^{5,6} Protective resin coatings have been shown to improve the surface characteristics, wear resistance, and mechanical properties of glass-ionomer-based restorative materials. Nanofilled protective coatings may provide additional surface protection and enhance restoration durability.^{7,8} Although Nano Coat has demonstrated beneficial effects on surface characteristics, limited evidence is available regarding its effect on the fracture resistance of Zirconomer.⁹⁻¹¹ Therefore, this study evaluated and compared the fracture resistance of Zirconomer restorations coated with G-Coat Plus and Fusion Nano Coat following thermocycling.

II. Material And Methods

This in vitro comparative study was carried out on extracted teeth in the Department of Conservative Dentistry and Endodontics at The Oxford Dental College and Hospital, Bengaluru, Karnataka. A total 45 intact maxillary premolars were used for this study.

Study Design: An in vitro study

Study Location: The Oxford Dental College and Hospital, Bengaluru, Karnataka.

Study Duration: March 2025 to March 2026.

Sample size: 45 samples.

Sample size calculation: The sample size for the present study was estimated using GPower software (latest ver. 3.1.9.7; Heinrich-Heine-Universitaet Duesseldorf, Duesseldorf, Germany). The sample size estimation was performed at 5% alpha error ($\alpha = 0.05$), with an effect size of 0.48 & the power of the study at 80%, demonstrated that a minimum of 45 samples will be needed for the present study. So, each study sub-group will consist of 15 samples. [15 samples x 3 groups = 45 samples].

Subjects & selection method:

Inclusion criteria:

1. Freshly extracted maxillary first premolars extracted for orthodontic purposes.
2. Intact, non-carious teeth.
3. Teeth with complete and normal crown morphology.
4. Teeth free from visible cracks, fractures, or structural defects.

Exclusion criteria:

1. Teeth with previous restorations.
2. Teeth with previous endodontic treatment or other endodontic manipulation.
3. Teeth with visible cracks or fractures.
4. Teeth with abrasion or significant surface defects.
5. Teeth with developmental or morphological anomalies.
6. Teeth with caries or other pathological defects.

Procedure methodology

A total of 45 intact maxillary first premolars, freshly extracted for orthodontic purpose were selected. Teeth were cleaned and mounted vertically in acrylic resin blocks. The teeth were then embedded in the resin up to 1 mm below the cemento-enamel junction. Standardized Class I cavities were prepared using a 245 bur (MANI, INC, Japan) and high-speed water-cooled hand piece (NSK, Japan). The dimensions of the cavity were in such a way that the width of the cavity was one-third of the intercuspal distance and depth of the cavity was 2 mm, which were confirmed using a calibrated periodontal probe.

The prepared teeth samples were then randomly divided into 3 groups (n=15) Group 1, Group 2 and Group 3. The grouping is shown below.

Group 1 - Control group - zirconomer;

Group 2 - zirconomer + G-COAT PLUS; and

Group 3 - zirconomer + Fusion Nano Coat.

Group 1 - teeth were restored with zirconomer improved (SHOFU, Japan) according to manufacturer's instructions.

Group 2 - teeth were restored with zirconomer and then G-COAT PLUS (GC, Japan) was applied on the restoration using a micro applicator and light cured for 20 seconds according to manufacturer's instructions.

Group 3 - teeth were restored with zirconomer and then Fusion Nano Coat (Prevest DenPro Limited, India) was applied on the restoration using micro applicator and light cured for 10 seconds according to manufacturer's instructions.

All the specimens were thermocycled for 500 cycles between 5°C and 55°C with 1 min in each cycle after 24 hours. Fracture resistance was tested for all specimens under compression using Universal Testing Machine. Each specimen was subjected to vertical compressive force with a 3 mm diameter stainless steel ball and a cross head speed of 1 mm/min. The force necessary to fracture each tooth was then recorded and statistically analyzed.



Figure 1: Fracture resistance test using Universal testing machine.

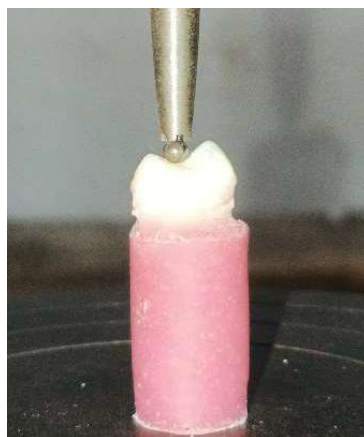


Figure 2: Fracture resistance test using vertical compressive force with a 3 mm diameter stainless steel ball and a cross head speed of 1 mm/min.

Statistical analysis

Statistical Package for Social Sciences [SPSS] for Windows Version 26.0 Released 2019. Armonk, NY: IBM Corp., was used to perform statistical analyses.

Descriptive Statistics:

Descriptive statistics (mean, standard deviation, standard error, and 95% confidence interval) were computed for each group, followed by assessment of the normality of distribution using the Shapiro–Wilk test and homogeneity of variances using Levene's test.

Inferential Statistics:

Welch's ANOVA Test followed by Games–Howell Post Hoc Test was used to compare the mean Fracture Resistance between 3 groups. The corresponding effect sizes (Cohen's d) were derived to quantify the magnitude of difference between groups.

The level of significance was set at $p < 0.05$.

III. Result

Table no. 1 Descriptive Statistics of Fracture Resistance (N) Across the Three Study Groups					
Group	N	Mean $\pm$ SD (N)	Std. Error	95% CI of Mean (N)	Min–Max (N)
Group I (Zirconomer)	15	902.17 $\pm$ 10.03	2.59	896.62 – 907.73	882.84 – 919.66
Group II (Zirconomer + G-Coat Plus)	15	1176.18 $\pm$ 25.72	6.64	1161.94 – 1190.43	1138.22 – 1223.50
Group III (Zirconomer + Fusion Nano Coat)	15	1022.30 $\pm$ 43.74	11.29	998.08 – 1046.52	934.35 – 1087.50

SD: Standard Deviation; CI: Confidence Interval; N: Newtons (unit of fracture load).

Welch's ANOVA, $F = 742.56$, $df = 2$ & $p < 0.001$ * - Statistically significant.

Table 1 presents the descriptive statistics of fracture resistance (in Newtons) recorded for the three study groups. The highest mean fracture resistance was observed in Group II (zirconomer restorations coated with G-Coat Plus; 1176.18 $\pm$ 25.72 N), followed by Group III (zirconomer coated with Fusion Nano Coat; 1022.30 $\pm$ 43.74 N), while Group I (uncoated zirconomer control; 902.17 $\pm$ 10.03 N) recorded the lowest mean fracture resistance among the three groups. The difference in the mean Fracture Resistance between 3 groups was statistically significant at $p < 0.001$.

Table no. 2 Test of Normality of Distribution — Shapiro–Wilk Test				
Group	N	Shapiro–Wilk value	p-value	Inference
Group I (Zirconomer)	15	0.981	0.978	Normally distributed
Group II (Zirconomer + G-Coat Plus)	15	0.934	0.311	Normally distributed
Group III (Zirconomer + Fusion Nano Coat)	15	0.966	0.789	Normally distributed

Table 2 summarizes the results of the Shapiro–Wilk test of normality, which was applied to assess whether the fracture resistance values within each group followed a Gaussian (normal) distribution, a prerequisite for the selection of an appropriate parametric or non-parametric inferential test. The Shapiro–Wilk statistic did not reach statistical significance for any of the three groups (Group I: $W = 0.981$, $p = 0.978$; Group II: $W = 0.934$, $p = 0.311$; Group III: $W = 0.966$, $p = 0.789$), indicating that the null hypothesis of normality could not be rejected for any group. The fracture resistance data in all three groups may therefore be regarded as normally distributed, thereby permitting the use of a parametric test for between-group comparison.

Table no. 3 Multiple Comparison of Mean Diff. in Fracture Resistance b/w 3 Groups Using Games–Howell Post Hoc Test					
(I) Group	(J) Group	Mean Diff. (N)	95% CI of Difference (N)		p-value (adj.)
			Lower	Upper	
Group I	Group II	–274.01†	–288.98	–259.04	<0.001*
Group I	Group III	–120.13†	–144.76	–95.50	<0.001*
Group II	Group III	153.88	126.76	181.01	<0.001*

Games–Howell post hoc test was used for pairwise comparison as it does not assume equal variances between groups.

† A negative mean difference indicates that Group (J) recorded a higher mean fracture resistance than Group (I). CI: Confidence Interval of the mean difference. * - Statistically significant.

Since Levene's test indicated unequal variances between groups, pairwise post hoc comparisons were performed using the Games–Howell test, which, unlike Tukey's HSD, does not assume equal variances or equal sample sizes between groups and is therefore appropriate under conditions of heteroscedasticity. As shown in Table 3, all three pairwise comparisons attained statistical significance at the 5% level ($p < 0.001$ for all comparisons), with none of the 95% confidence intervals of the mean difference crossing zero. Zirconomer coated with G-Coat Plus (Group II) exhibited a significantly higher fracture resistance than uncoated zirconomer (Group I), with a mean difference of 274.01 N (95% CI: 259.04 to 288.98 N) — the largest pairwise difference observed in the study. Zirconomer coated with Fusion Nano Coat (Group III) also demonstrated a significantly higher fracture resistance than uncoated zirconomer (Group I), with a mean difference of 120.13 N (95% CI: 95.50 to 144.76 N). Between the two coated groups, G-Coat Plus-coated specimens (Group II) outperformed Fusion Nano Coat-coated specimens (Group III) by a mean of 153.88 N (95% CI: 126.76 to 181.01 N). Taken together, these findings indicate the following order of fracture resistance among the tested groups: Group II (G-Coat Plus) > Group III (Fusion Nano Coat) > Group I (uncoated control).

Table no. 4 Effect Size (Cohen's d) for Pairwise Group Comparisons			
Pairwise Comparison	Cohen's d	95% CI of d	Magnitude of Effect
Group I vs Group II	14.04	10.29 to 17.78	Large
Group I vs Group III	3.79	2.56 to 5.01	Large
Group II vs Group III	4.29	2.96 to 5.62	Large

Cohen's d effect size interpretation: 0.2 = small, 0.5 = medium, 0.8 = large (Cohen, 1988).

CI: 95% Confidence Interval of Cohen's d, computed using the pooled standard deviation of the compared groups.

Table 4 presents the standardized effect size (Cohen's d) with 95% confidence intervals for each pairwise comparison, quantifying the magnitude, rather than merely the statistical significance, of the observed differences. All three pairwise comparisons yielded Cohen's d values well in excess of the conventional threshold of 0.8, corresponding to a “large” effect size by Cohen's classification, with the comparison between Group I and Group II yielding an exceptionally large effect size ($d = 14.04$, 95% CI: 10.29 to 17.78). Such large and non-overlapping effect-size confidence intervals reinforce the clinical, and not merely statistical, relevance of the observed differences — the application of both G-Coat Plus and Fusion Nano Coat over zirconomer restorations was associated with an enhancement of fracture resistance relative to the uncoated control, with G-Coat Plus producing a substantially greater improvement than Fusion Nano Coat.

IV. Discussion

The present in vitro study evaluated and compared the fracture resistance of Class I Zirconomer restorations with and without the application of two protective resin coatings, G-Coat Plus and Fusion Nano Coat, following thermocycling. The results demonstrated a statistically significant difference among the three groups. Zirconomer coated with G-Coat Plus exhibited the highest mean fracture resistance (1176.18 ± 25.72 N), followed by Fusion Nano Coat (1022.30 ± 43.74 N), while uncoated Zirconomer demonstrated the lowest value (902.17 ± 10.03 N). Welch ANOVA revealed a significant difference among the groups ($P < 0.001$), and Games–Howell post hoc analysis demonstrated significant differences between every pair of groups ($P < 0.001$). Therefore, the null hypothesis was rejected.

The fracture resistance of a restored tooth is influenced by the amount of remaining tooth structure, cavity configuration, restorative material, and the interaction between the restoration and tooth substrate. Previous studies have demonstrated differences in fracture resistance among teeth restored with different restorative materials in Class I and other cavity preparations.^{1,2} The removal of tooth structure during cavity preparation can alter stress distribution and increase the susceptibility of teeth to fracture. These findings provide a rationale for evaluating restorative approaches that can improve the resistance of restored teeth to functional loading.

Conventional glass ionomer cements have limitations in their resistance to fracture and functional stresses, particularly because of their relatively lower fracture toughness.^{3,4} Zirconomer was developed as a zirconia-reinforced glass ionomer with improved mechanical properties compared with conventional glass-

ionomer materials. The incorporation of zirconia particles has been associated with improvements in strength and other mechanical characteristics of the material.^{5,6} Previous investigations have also evaluated the fracture resistance of Zirconomer in prepared teeth, supporting its potential as a restorative material for posterior applications.⁵

In the present study, application of G-Coat Plus resulted in a substantial increase in fracture resistance compared with uncoated Zirconomer. This finding may be attributed to the protective resin layer formed over the restoration. Lohbauer et al. reported that a nanofilled resin coating could improve the strength and wear resistance of glass-ionomer cement, indicating that surface coating can contribute to improved mechanical performance.⁷ Similarly, Bagheri et al. demonstrated that G-Coat Plus influenced the mechanical properties of glass-ionomer cements, supporting the beneficial effect of resin coating on the underlying restorative material.⁸

The findings are also consistent with the study by Thomas et al., which demonstrated beneficial effects of protective coating agents on the properties of glass-ionomer cement and Zirconomer.⁹ The application of a protective coating may limit direct exposure of the underlying material to moisture and mechanical challenges and may provide a more resistant surface. Elshawadfy et al. similarly reported improved surface wear and fracture resistance following application of a nanofilled coating to a glass-hybrid restorative material.¹⁰ These findings support the possibility that the resin coating contributes not only to surface protection but also to improved resistance to fracture.

Fusion Nano Coat also demonstrated significantly greater fracture resistance than uncoated Zirconomer. Although the present study provides direct evidence regarding its effect on Zirconomer fracture resistance, published evidence specifically evaluating Fusion Nano Coat with Zirconomer appears to be limited. Sivasankari et al. evaluated a Prevest DenPro nanofilled surface coating and reported reduced surface roughness and microbial adhesion following coating application.¹¹ Although that investigation was performed on provisional restorative materials and did not evaluate fracture resistance, the findings suggest that modification and sealing of the restorative surface may contribute to improved surface characteristics.

The difference between the two coated groups is noteworthy. G-Coat Plus demonstrated a higher mean fracture resistance than Fusion Nano Coat, suggesting that the two coating systems may differ in their interaction with the underlying restorative material, degree of surface protection, resin characteristics, or polymerization behavior. However, because the present study did not evaluate coating thickness, degree of conversion, interfacial adaptation, or fracture morphology, the exact reason for the difference cannot be established.

The fracture resistance values observed in the present study are also consistent with the broader evidence that restorative material selection and restoration configuration influence the mechanical performance of restored teeth. Studies involving glass-hybrid and high-viscosity glass-ionomer restorative materials have demonstrated differences in fracture resistance depending on the restorative material and cavity configuration.^{12,13} Investigations of weakened premolars have further shown that the type of restorative material and restorative approach can significantly influence stress distribution and resistance to fracture.^{14,15} Similar effects have been reported for different restorative techniques in root-filled premolars.¹⁶

The clinical performance of glass-hybrid restorative systems has also been evaluated over extended periods, with evidence supporting their ability to function under clinical conditions.¹⁷ However, laboratory fracture resistance should not be directly equated with long-term clinical survival. The present findings therefore demonstrate a mechanical advantage of protective coating under the specific experimental conditions rather than establishing superior clinical longevity.

Thermocycling was incorporated into the present protocol to subject the restorations to repeated temperature changes before fracture testing. Thermal cycling can produce stresses at the tooth-restoration interface because of differences in the thermal behavior of tooth structure and restorative materials. Previous studies evaluating fracture resistance have incorporated thermocycling to simulate aspects of the thermal challenges encountered intraorally.¹⁸ In addition, a recent systematic review has highlighted the potential influence of resin coatings on the properties and performance of glass-ionomer cements, supporting the broader rationale for investigating protective surface treatments.¹⁹

The present study has certain limitations. It was conducted in vitro using a relatively small sample size, and the extracted teeth may exhibit natural variations in morphology and structural characteristics. Only 500 thermocycles and a single static compressive loading protocol were used, which cannot reproduce the complex cyclic and multidirectional forces occurring clinically. Furthermore, the study evaluated fracture resistance as the primary outcome without examining the mode or origin of fracture. Future investigations using larger sample sizes, increased thermocycling, cyclic fatigue loading, microscopic evaluation of fracture patterns, and longer-term aging protocols would provide further insight into the mechanisms underlying the observed differences.

Within the limitations of this in vitro study, both protective coatings significantly increased the fracture resistance of Class I Zirconomer restorations following thermocycling. G-Coat Plus demonstrated the highest

fracture resistance, followed by Fusion Nano Coat, while uncoated Zirconomer showed the lowest fracture resistance. These findings suggest that application of a protective resin coating may enhance the mechanical performance of Zirconomer restorations; however, further laboratory and clinical studies are required before these findings can be translated into definitive clinical recommendations.

V. Conclusion

The type of protective coating significantly influenced the fracture resistance of Class I Zirconomer restorations after thermocycling.

G-Coat Plus showed the highest fracture resistance, followed by Fusion Nano Coat and uncoated Zirconomer. Both coatings improved fracture resistance compared with uncoated Zirconomer. Further studies are required to confirm these findings under clinical conditions.

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