

The Effect of Coca-Cola on the Compressive Strength of Three Restorative Materials Used in Pediatric Dentistry: An In Vitro Comparative Evaluation

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ABSTRACT

Background and Objective: The consumption of acidic soft drinks has become common in young children, and their effects on teeth and restorative materials have become a concern for dentists. This in vitro study aimed to compare and analyze the compressive strength of three commonly used restorative materials in pediatric dentistry, Glass Ionomer Cement (GIC), Compomer, and Giomer, after immersion in Coca-Cola (as an acidic beverage) and distilled water (DW) (as a control).

Materials and Methods: Sixty cylindrical specimens were fabricated and divided into three main groups (n=20) for each material, and further randomly subdivided into two equal subgroups (n=10). Each subgroup was then immersed in either Coca-Cola or distilled water for seven days, with the liquids being changed every day. Compressive strength was tested using a Universal Testing Machine. The data were analyzed using two-way ANOVA and Tukey's HSD post hoc test. The percentage of reduction of strength was also calculated for each material.

Results: All materials showed a statistically significant decrease in compressive strength after Coca-Cola exposure, $p < 0.001$. The mean compressive strengths of Giomer, Compomer, and GIC in distilled water were 276.85 MPa, 182.89 MPa and 103.7 MPa, respectively. The reduction in strength from distilled water to Coca-Cola for Compomer, Giomer, and GIC was 18.69%, 15.28%, and 11.97%, respectively.

Conclusion: Acidic exposure from beverages like Coca-Cola reduces the compressive strength of restorative materials, with Compomer being the most affected. GIC showed the highest resistance to acidic degradation, which may be attributed to the absence of a resin matrix.

Keywords: Compressive Strength, Pediatric Dentistry, Glass Ionomer Cements, Compomers, Giomers, Carbonated Beverages, Dental Materials

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INTRODUCTION

Durability and mechanical performance of materials are critical in pediatric restorative dentistry. In addition to aesthetics and handling properties, degradation resistance of the material under different oral conditions must also be considered by dentists. Common materials for pediatric cases are GIC, Giomer and Compomer. Each material offers advantages such as fluoride release, adhesion, ease of use and handling, which make these materials useful for caries management in children.¹

Recently, there has been renewed concern about the negative effects of children's eating habits, particularly the excessive consumption of acidic and sweet beverages, on the strength and longevity of restorations. One example of an acidic beverage is Coca-Cola, which is consumed very frequently by children and has caused concern about the damage to dental structures and restorative materials.²

Although the materials are generally designed to withstand intraoral mechanical stresses, their behavior in chemically aggressive environments such as acidic beverages remains of clinical interest. The structural integrity of restorative materials may be degraded by exposure to acid, decreasing their compressive strength and durability.³

Accordingly, the present study was conducted to

evaluate the compressive strength of GIC, Compomer and Giomer after Coca-Cola exposure, compared with distilled water as a control medium. To the best of our knowledge and based on the available literature, no prior studies have compared the effect of Coca-Cola on the compressive strength of these three restorative materials under standardized conditions.

This research aimed to provide an evidence-based evaluation of the behavior of each material (Compomer, Giomer, and GIC) under the acidic challenge of Coca-Cola and to determine which material showed the greatest resistance under such conditions. It was hypothesized that the materials would be affected by immersion in Coca-Cola, and each material would show significant differences in resistance to acidic degradation.

METHODS

In this in vitro comparative study, the effect of Coca-Cola® (The Coca-Cola Company, USA) on the compressive strength of three restorative materials in pediatric dentistry was evaluated: GIC, Compomer and Giomer. Testing was done in the Department of Mechanics and Mechatronics, College of Engineering Salahaddin University-Erbil.

Table 1. Composition and Manufacturers of the Restorative Materials Used in the Study

#	Materials	Composition	Brand name	Manufacturer
1	GIC	·Fluoroaluminosilicate glass · Polybasic carboxylic acid ·Polyacrylic acid ·Polyacrylic acid powder ·distilled water	Fuji IX Glass Ionomer A2	GC/Japan
2	Giomer	·Bis-GMA ·Triethylene-glycol dimethacrylate ·Pre-reacted glass ionomer filler ·Camphoroquinone ·Aluminum oxide	Beautifil II Giomer A2	Shofu/Japan
3	Compomer	·Bis-GMA ·Urethane dimethacrylate ·Triethylene-glycol dimethacrylate ·Polyacrylic acid ·Fillers (Silica, Barium glass, Strontium glass) ·Initiators, Accelerators, and Stabilizers	Composan Glass A2	Promedica/ Germany

Specimen Preparation

Sixty cylindrical specimens (6 mm height x 4 mm diameter) were prepared in stainless steel split molds in accordance with ADA Specification No. 27,⁴ and divided into three groups of twenty according to the type of restorative material. Each material group was further subdivided into two subgroups (n = 10): one group in distilled water

and the other in Coca-Cola.

All materials were prepared based on the manufacturer's instructions.

Compomer and Giomer were placed into the molds and light-cured in fast mode (LED II, Proclinc) for 40 seconds on both sides,⁵ with the curing tip 1 mm away from the specimen surface, using an irradiance of 1200 mW/cm². In the case of

GIC, the Fuji IX capsule was pre-mixed with a mechanical mixer and injected into the mold. Glass slides and Mylar strips were used to flatten and standardize specimen surfaces, and excess ma-

terial was removed by light pressure. After setting and removal, the specimens were inspected for air bubbles or surface irregularities, and defective specimens were discarded.⁶



Figure 1. The restorative materials used in the study. (A- Compomer B- Giomer C- GIC)

Storage and Immersion Protocol

All specimens were first set in distilled water at 37°C for 24 hours to simulate oral conditions.⁷ Each subgroup was then immersed continuously for 24 hours per day over seven consecutive days in 50 mL of Coca-Cola® (The Coca-Cola Company, USA) or distilled water, with the liquid replaced daily, to replicate prolonged real-life exposure from frequent carbonated drink consumption.⁸⁻¹⁰

Compressive Strength Testing

A Universal Testing Machine (Gunt Hamburg WP 300) was used for the study, as shown in Figure 2. The specimens were placed vertically between the plates, and the compressive load was applied at a crosshead speed of 1 mm/min at (15 mm diameter) until fracture occurred. Maximum load at fracture

was measured in Newtons.¹¹

Compressive Strength Calculation

The compressive strengths were obtained from the following equation:

$$\sigma_c = \frac{P}{A} = \frac{P}{\frac{\pi d^2}{4}} = \frac{4P}{\pi d^2}$$

Where:

- * = compressive strength in MPa.
- * P is maximum load at fracture (N).
- * d is specimen diameter in mm.

This method is commonly used to measure fracture resistance under axial stress assessment in dental materials research.¹²

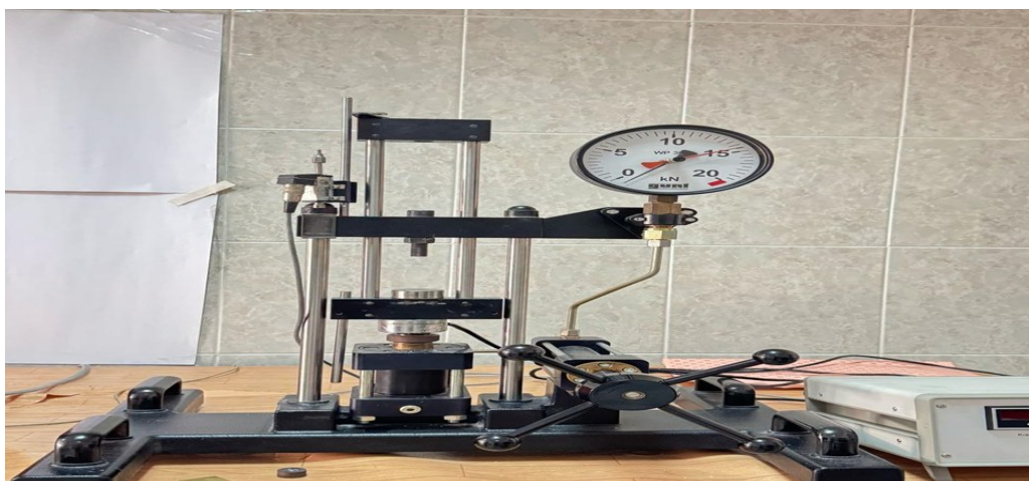


Figure 2. The Universal Compressive Strength machine used during the study

Statistical Analysis

For each group, descriptive statistics were computed. For statistically significant differences among the 3 groups, Levene’s test for equality of variances followed by two-way ANOVA were done. Tukey’s HSD post hoc tests for multiple comparisons were conducted. Statistical significance was set at $p < 0.05$.¹³

RESULTS

Compressive strength values of the three restorative materials (Compomer, Giomer, and GIC) in two conditions—distilled water (control) and Coca-Cola (experimental)—were recorded in megapascals (MPa) for the samples in each group. Descriptive statistics were calculated for each group to characterize the central tendency and spread of the compressive strength values.

To compare the effects of material type and exposure condition on compressive strength, a two-way ANOVA was used. The test revealed whether statistically significant differences existed among the six groups (three materials \times two conditions). A post hoc Tukey’s HSD test was subsequently used to determine which pairs of groups were statistical-

ly different.

Moreover, the percentage loss in the compressive strength of each material after being subjected to Coca-Cola was determined.

These values were also compared using independent t-tests to determine whether the observed differences in percentage decrease across materials were statistically significant.

All findings were presented in tabular format and, when relevant, as bar graphs, with error bars indicating standard deviations. This analysis assessed both the absolute and relative effects of exposure to acidic drinks on the mechanical properties of restorative materials used in pediatric dentistry.

A p-value less than 0.05 was used as the threshold of statistical significance. All the analyses were performed using SPSS version 27. Figure 3 shows the mean, standard deviation, and range of compressive strength values per group. Giomer stored in distilled water showed the highest mean compressive strength (276.85 MPa), whereas GIC stored in Coca-Cola showed the lowest mean (91.3 MPa). In all three materials, compressive strength decreased consistently after Coca-Cola exposure.

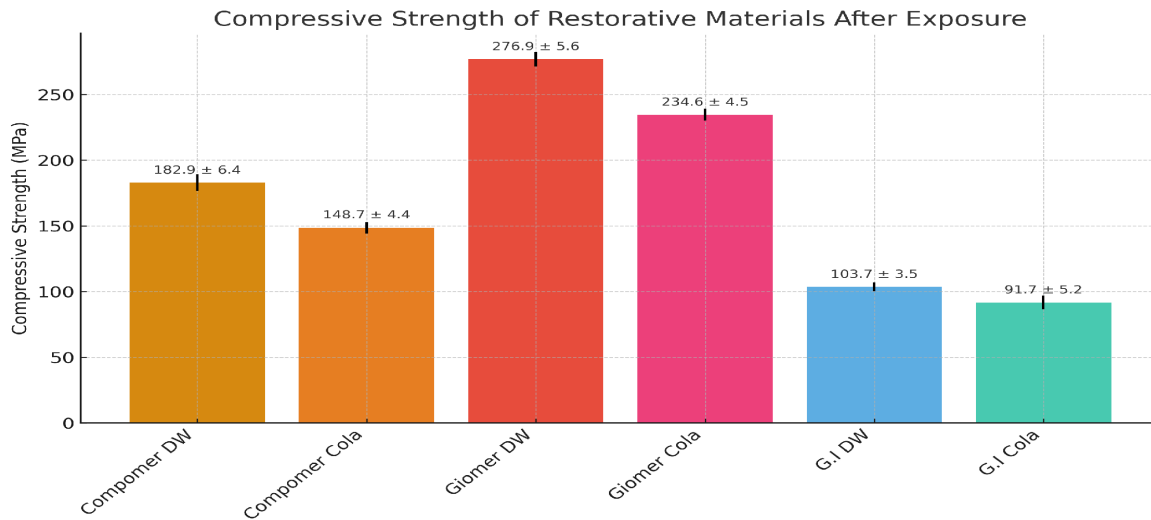


Figure 3. Bar graph showing compressive strength values with standard deviations for each group

Table 2 summarizes the percentage reduction in compressive strength of each material following Coca-Cola exposure. Compomer experienced the

greatest reduction (18.69%), followed by Giomer (15.28%) and GIC (11.97%).

Table 2. Mean Compressive Strength and Percentage Decrease in Strength

Material	Mean (DW) MPa	Mean (Cola) MPa	% Decrease	p-value
Compomer	182.89	148.72	18.69%	< 0.001
Giomer	276.85	234.55	15.28%	< 0.001
GIC	103.7	91.3	11.97%	< 0.001

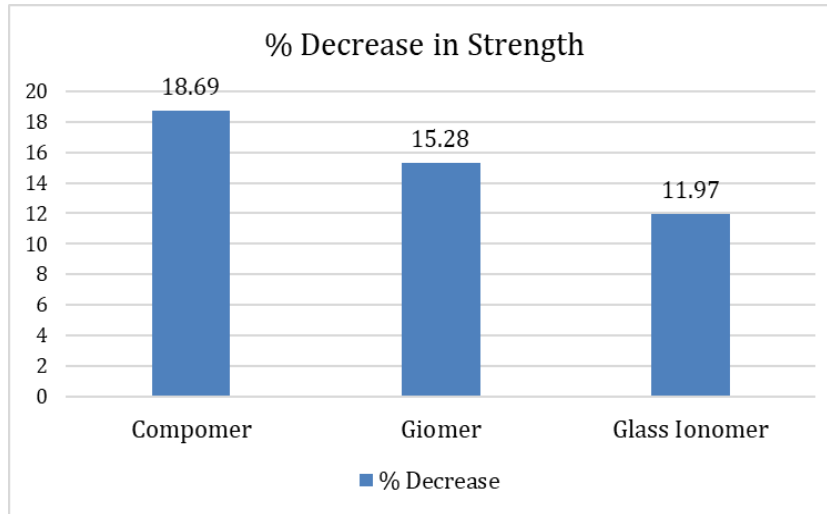


Figure 4. Percentage decrease in compressive strength after Coca-Cola exposure across materials

Pairwise comparisons between each material in distilled water and Coca-Cola

Table 3 reports independent t-tests of the compressive strength of each restorative material stored in distilled water versus Coca-Cola. All

comparisons had a statistically significant reduction in compressive strength after Coca-Cola exposure ($p < 0.001$), suggesting that the acidic environment weakened each material.

Table 3. Comparison of the Reduction in Compressive Strength of the Materials from DW to Coca-Cola

Material	Group 1 (DW)	Group 2 (Cola)	Mean Difference (MPa)	p-value	95% Confidence Interval
Compomer	Compomer DW	Compomer Cola	-34.17	< 0.001	-40.91 to -27.44
GIC	G.I DW	G.I Cola	-12.41	< 0.001	-19.15 to -5.66
Giomer	Giomer DW	Giomer Cola	-42.29	< 0.001	-49.03 to -35.55

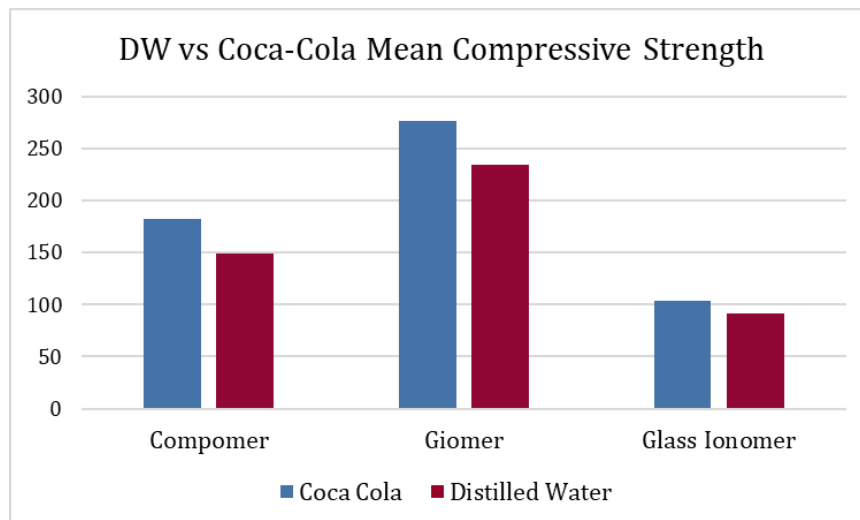


Figure 5. Comparison of compressive strength in DW vs Coca-Cola for each material

Assumption Testing

Levene's test for equality of variances showed no significant differences in variance across groups ($p = 0.154$), supporting the assumption of homogeneity of variance required by ANOVA.

Two-Way ANOVA Findings

A two-way ANOVA was conducted to evaluate the impact of material type and storage conditions on compressive strength. The study showed that the type of material had a statistically significant main effect, $F(2, 54) = 4846.02$, $p < 0.001$, partial $\eta^2 = 0.994$. This means that the compressive strength of the investigated materials was significantly different.

There was also a significant main impact of storage condition, $F(1, 54) = 506.73$, $p < 0.001$, partial $\eta^2 = 0.904$, with specimens stored in distilled water showing greater strength values than those stored in Coca-Cola. Additionally, a significant interaction between material type and storage con-

dition was identified, $F(2, 54) = 45.96$, $p < 0.001$, partial $\eta^2 = 0.630$, indicating that the extent of strength degradation induced by cola differed across various materials. The model accounted for 99.5% of the variance in compressive strength ($R^2 = 0.995$, adjusted $R^2 = 0.994$).

As seen in Table 4, the intergroup comparison between the materials immersed in distilled water, and the materials immersed in Coca-Cola showed statistically significant differences in compressive strength among them. In both liquids, Giomer exhibited the greatest strength, followed by Compomer, while GIC had the lowest strength.

All intergroup comparisons were statistically significant ($p < 0.001$), indicating that each material behaved differently depending on exposure condition. Among all groups, Giomer stored in distilled water recorded the highest compressive strength, while GIC stored in Coca-Cola recorded the lowest.

Table 4. Tukey's HSD Post Hoc Comparisons (Intergroup Comparison)

Group 1	Group 2	Mean Difference (MPa)	p-value	95% CI
Compomer Cola	Compomer DW	34.17	< 0.001	27.44 - 40.91
Compomer Cola	G.I. Cola	-57.43	< 0.001	-64.17 - -50.70
Compomer Cola	G.I. DW	-45.02	< 0.001	-51.76 - -38.29
Compomer Cola	Giomer Cola	85.83	< 0.001	79.09 - 92.57
Compomer Cola	Giomer DW	128.13	< 0.001	121.39 - 134.86
Compomer DW	G.I. Cola	-91.61	< 0.001	-98.35 - -84.87
Compomer DW	G.I. DW	-79.20	< 0.001	-85.94 - -72.46
Compomer DW	Giomer Cola	51.66	< 0.001	44.91 - 58.40
Compomer DW	Giomer DW	93.96	< 0.001	87.22 - 100.71
G.I. Cola	G.I. DW	12.41	< 0.001	5.66 - 19.15
G.I. Cola	Giomer Cola	143.27	< 0.001	136.53 - 150.02
G.I. Cola	Giomer DW	185.56	< 0.001	178.82 - 192.31
G.I. DW	Giomer Cola	130.86	< 0.001	124.12 - 137.60
G.I. DW	Giomer DW	173.15	< 0.001	166.41 - 179.90
Giomer Cola	Giomer DW	42.29	< 0.001	35.55 - 49.03

DISCUSSION

This study was performed to evaluate the effect of the acidic soft drink Coca-Cola on the compressive strength of three common restorative materials in pediatric dentistry: GIC, Compomer, and Giomer. The three materials were selected because of their common use in pediatric dentistry. Coca-Cola was

selected as the experimental liquid due to its increased consumption among children in recent years.¹⁴

According to the results, exposure to Coca-Cola significantly reduced the compressive strength of all materials, likely due to its acidic nature. This suggests that acidic environments may compro-

mise the durability of restorative materials.

Among the three tested materials, GIC showed the lowest percentage reduction (11.97%), Compomer the greatest (18.69%), and Giomer in between (15.28%). These results are consistent with earlier studies showing that acidic beverages such as Coca-Cola degrade the mechanical properties of esthetic restorative materials by penetrating the matrix and softening the structure.¹⁵

The relatively better performance of GIC in acidic conditions may be because of its composition, fluoroaluminosilicate glass and polyacrylic acid that set via an acid-base reaction, rather than a resin matrix. This lack of a resin matrix prevents chemical softening by acidic beverages. Furthermore, studies have shown that hydrophilic and inorganic GICs are more resistant to surface degradation and matrix breakdown at low pH. This explains why GICs lost less compressive strength under Coca-Cola exposure than resin-based materials.^{16,17}

In contrast, Compomers and Gioners have better baseline mechanical properties due to the Bis-GMA and UDMA resin matrices but are susceptible to more acid-induced degradation. In general, resin matrices take up water and acidic components from the environment and thus become plasticized and softened, resulting in reduced mechanical strength.¹⁷

The baseline compressive strength of Giomer was higher than Compomer, probably because of its cross-linked polymer matrix and pre-reacted glass fillers (PRG). With the PRG technology in Giomer, the glass fillers are pre-reacted with polyacrylic acid, yielding a more stable, denser material than the gel network formed by acid-base reactions in Compomers. This makes Giomer stronger in compression and tougher overall.¹⁸

Although Compomer exhibited a greater percentage reduction than Giomer, the difference was not statistically significant.

Further, the statistically significant differences between the groups, as indicated by the two-way ANOVA and Tukey's HSD post hoc test, indicate that both the type of restorative material and the exposure medium are important factors in determining compressive strength.

From a clinical standpoint, when choosing restorative materials, dentists should consider not only mechanical requirements but also the oral environment. According to the results, Giomer may be recommended for restorations in cases where high

compressive strength is needed; at the same time, GIC might be preferred in environments requiring some acid resistance, despite its lower compressive strength. However, these recommendations should be regarded cautiously due to in vitro conditions.

CONCLUSION

The study found that Giomer had superior compressive strength compared to Compomer and GIC, with GIC being the weakest. Coca-Cola reduced the compressive strength of all three materials tested, with Compomer being the most affected and GIC the least. While GIC was shown to be the most resistant to degradation, its final strength in Coca-Cola remains lower than that of Giomer after reduction.

Dentists may need to consider children's dietary habits when choosing specific types of restorative materials to ensure longevity. The null hypothesis was rejected because the compressive strengths of the materials tested differed, and all three materials were affected by immersion in Coca-Cola.

While this study provided an important perspective, it was conducted under in vitro conditions that do not fully replicate the oral environment. Variables such as saliva composition and oral hygiene were not accounted for. In addition, the exposure period was only seven days, and compressive strength was the only property assessed. More research is needed on the impact of acidic beverages on the mechanical properties of restorative materials to support these findings and their applicability in clinical practice.

Conflict of Interest

The authors declare no conflicts of interest.

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