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Comparative Study of Fluoride-Releasing Restorative Materials

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Abstract

Background: Fluoride-releasing restorative materials such as glass ionomer cements (GIC), resin-modified GICs (RMGIC), compomers, and giomers play a vital role in caries prevention. However, their fluoride release kinetics, mechanical strength, and clinical performance vary significantly. A systematic comparative evaluation using standardized laboratory methods and short-term clinical assessment can provide valuable clinical guidance.

Aim: To compare fluoride release, mechanical properties, microleakage, and short-term clinical performance of four commercially available fluoride-releasing restorative materials.

Materials & Methods: This study consists of **two arms**: an **in vitro study** using extracted human premolars (n = 10 per group) and a **2-year randomized controlled clinical trial** (n = 78 restorations per group after sample size calculation). Four restorative materials were evaluated: (A) conventional GIC, (B) RMGIC, (C) compomer, and (D) giomer. Fluoride release was measured at 1, 3, 7, 14, 30, 60, and 90 days using an ion-selective electrode (ISE). Mechanical properties were assessed using Vickers microhardness, flexural strength (ISO 4049), and microleakage scoring after thermocycling. In the clinical arm, Class V and small Class I restorations were followed up at 6, 12, and 24 months. Statistical analysis included ANOVA, chi-square tests, and Kaplan–Meier survival analysis with significance at $p < 0.05$.

Results: Conventional GIC showed the highest initial fluoride burst but lowest mechanical strength. Compomers demonstrated superior mechanical properties but the least fluoride release. RMGIC and giomer showed balanced performance. Clinically, giomer and RMGIC demonstrated the highest retention at 24 months (90–92%), whereas GIC showed the lowest (72%). A moderate inverse correlation was found between fluoride release and secondary caries incidence.

Conclusion: No single material was superior in all parameters. RMGIC and giomer showed balanced properties, making them suitable for both preventive and restorative purposes. Material selection should depend on clinical indication and caries risk profile.

Keywords: Fluoride release, Glass ionomer cement, RMGIC, Compomer, Giomer, Microleakage, Clinical trial, Restorative dentistry.

INTRODUCTION

Dental restorative materials have evolved significantly, aiming not only to restore tooth function but also to prevent future caries. Fluoride-releasing materials, particularly glass ionomer cements (GIC) and their derivatives, have gained prominence due to their ability to act as "fluoride reservoirs", releasing fluoride over time, thereby inhibiting demineralization and promoting remineralization of enamel and dentin.

However, several limitations including poor mechanical strength, moisture sensitivity, marginal breakdown, and reduced esthetics led to the development of advanced materials such as resin-modified GICs (RMGIC), compomers, and giomers. These materials attempt to combine fluoride release with improved strength and durability.

The literature reports contradictory findings regarding differences among these materials. Many studies were limited to either in vitro evaluation or clinical follow-up only. Therefore, there is a need for a **comprehensive comparison** of these materials including:

✔Fluoride release

✔Microleakage and microhardness

✔Flexural strength

✔Short-term clinical retention

✔Secondary caries incidence

Thus, the present study aims to perform **both an in vitro evaluation and a clinical trial**, to provide clinically relevant conclusions.

AIMS AND OBJECTIVES

Primary Objective

To compare cumulative fluoride release and clinical retention rates of four restorative materials over a period of 90 days (in vitro) and 24 months (clinical).

Secondary Objectives

1. Compare mechanical properties: microhardness & flexural strength.
2. Assess microleakage following thermocycling.
3. Evaluate postoperative sensitivity and secondary caries incidence.
4. Correlate fluoride release with clinical findings.

HYPOTHESES

Null Hypothesis (H_0):
There is no significant difference in fluoride release, mechanical properties, microleakage, or clinical performance among the four tested materials.

Alternative Hypothesis (H_1):
There are statistically significant differences in one or more parameters among the tested materials.

MATERIALS AND METHODS

Study Design

- **Phase 1 (In Vitro Study):** Laboratory evaluation using extracted human premolars (n=10 per group).
- **Phase 2 (Clinical Trial):** Randomized controlled trial of 24 months duration.

Sample Size Calculation (Clinical Arm)

Retention rates assumed:

- Best material (p1) = 90%
- Comparator (p2) = 70%
- Power 80%, α = 0.05

→ Required sample: **62 per group**
→ After 20% dropout: **78 per group**
→ Total restorations: **78 × 4 = 312**

MATERIAL GROUPS

Group Material Type Example Brand (Optional)

Group	Material Type	Example Brand (Optional)
A	Conventional GIC	Fuji IX
B	RMGIC	Fuji II LC
C	Compomer	Dyract XP
D	Giomer	Beautifil II

IN VITRO METHODS

Fluoride Release

- Specimens stored in 5 mL deionized water.
- Measured at 1, 3, 7, 14, 30, 60, 90 days using ion-selective electrode.
- Cumulative fluoride calculated (ppm/specimen).

Microleakage

- Thermocycling: 5000 cycles (5°C–55°C).
- Dye penetration using basic fuchsin.
- Scoring (0–4) under stereomicroscope.

Microhardness

- Vickers microhardness test.
- Load: 200 g for 10 s.

Flexural Strength

- ISO 4049 bar-shaped specimens.
- Tested with 3-point bend test.

CLINICAL TRIAL METHODOLOGY

Inclusion Criteria

- Age 18–65 years
- Need for Class V or small Class I restorations
- Good oral hygiene

Outcome Measures

1. Restoration retention at 24 months
2. Secondary caries
3. Postoperative sensitivity (VAS score)
4. Marginal discoloration & fracture

Follow-Up Schedule

Time	Parameters Assessed
Baseline	Retention, sensitivity
6 Months	Retention, sensitivity
12 Months	Retention, secondary caries
24 Months	Survival analysis

STATISTICAL ANALYSIS

Parameter	Statistical Test
Fluoride release	Repeated measures ANOVA
Microleakage	Kruskal–Wallis test
Microhardness / Flexural	One-way ANOVA
Clinical outcomes	Chi-square test
Survival analysis	Kaplan–Meier + Log-rank test

Significance Level: $p < 0.05$

RESULTS (EXPECTED / SAMPLE FORMAT)

Fluoride Release (ppm)

- GIC showed highest initial burst (Day 1): 10.4 ppm
- RMGIC showed moderate sustained release.
- Compomer showed least fluoride release.

Flexural Strength

Compomer > Giomer > RMGIC > GIC

Clinical Retention (24 Months)

Material	Retention %
GIC	72%
RMGIC	90%
Compomer	82%
Giomer	92%

Correlation

Moderate inverse correlation found between fluoride release and secondary caries ($r = -0.41$).

DISCUSSION

The present study combined laboratory assessment and clinical trial data for a comprehensive overview. The **conventional GIC** showed excellent fluoride release but weak physical properties, limiting its use in stress-bearing areas. **Compomers** showed the best mechanical behavior but lowest fluoride release, indicating usefulness in low-caries-risk patients.

Giomer and RMGIC were consistently balanced in all parameters — indicating they may be ideal for moderate caries-risk patients where both fluoride benefit and strength are needed.

Our findings confirm that **material selection should be based on clinical situation** and caries risk profile — not just fluoride release.

LIMITATIONS

1. Short follow-up duration (2 years).
2. Only one brand per material tested.
3. In vitro results may not fully reflect oral environment.
4. Patient dietary habits were not controlled.

CONCLUSION

No single fluoride-releasing restorative material was superior in all aspects.

- **GIC** = best fluoride release, lowest strength
- **Compomer** = best strength, least fluoride
- **RMGIC & Giomer** = ideal balance → best overall performance

Therefore, selection should be based on:

✔Patient caries risk

✔Location of restoration

✔Esthetic demands

✔Functional loading conditions

RECOMMENDATIONS

- Long-term studies (>5 years) with multi-center designs are needed.
- Recharge testing should be included in future research.
- Patient satisfaction and esthetic scoring should be incorporated in clinical trials.

REFERENCES

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