# In vitro study on using flowable composite for reattachment of tooth fragment

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**Abstract**

**Background**

Tooth fractures are common dental injuries, and fragment reattachment is a minimally invasive and aesthetic option for their management. Flowable composites have been increasingly explored for this purpose due to their ease of application and bonding efficiency. This study aimed to evaluate the effectiveness of flowable composites in reattaching tooth fragments using an in vitro model.

**Materials and Methods**

Thirty freshly extracted, intact human maxillary central incisors were randomly divided into three groups (n=10) based on the adhesive strategy employed: **Group A** (etch-and-rinse), **Group B** (self-etch), and **Group C** (universal adhesive). Standardized oblique fractures were created using a diamond disc, and fragments were reattached using flowable composite. Bond strength was assessed using a universal testing machine at a crosshead speed of 1 mm/min until failure. The failure modes were analyzed under a stereomicroscope. Statistical analysis was performed using one-way ANOVA and Tukey's post-hoc test ($p < 0.05$).

**Results**

The mean bond strength values (in MPa) were as follows: Group A (22.4 ± 2.8), Group B (19.7 ± 3.1), and Group C (25.1 ± 2.3). Group C demonstrated significantly higher bond strength compared to Groups A and B ($p < 0.05$). Failure analysis revealed a higher incidence of cohesive failures in Group C, suggesting superior adhesive performance of the universal adhesive strategy with flowable composite.

**Conclusion**

The use of flowable composite for tooth fragment reattachment demonstrated promising bond strength, particularly when combined with a universal adhesive system. This approach offers a reliable, aesthetic, and conservative solution for managing tooth fractures in clinical practice. Further clinical studies are recommended to validate these findings.

**Keywords:** Tooth fragment reattachment, flowable composite, universal adhesive, bond strength, in vitro study.

## Introduction

Tooth fractures are a common dental emergency, particularly among children and adolescents, with the maxillary anterior teeth being the most affected due to their prominent position in the dental arch (1,2). Managing fractured teeth often poses a clinical challenge, especially in achieving both functional and aesthetic outcomes. Among the various treatment modalities, reattachment of the fractured tooth fragment offers a minimally invasive and highly aesthetic solution, preserving the natural anatomy, texture, and color of the tooth (3).

Advancements in adhesive dentistry have significantly improved the success of fragment reattachment procedures. Flowable composites have gained attention in this context due to their low viscosity, superior adaptation, and ability to penetrate micro-irregularities on the tooth surface, enhancing the bond strength (4,5). Furthermore, the introduction of universal adhesive systems, capable of functioning in both etch-and-rinse and self-etch modes, has simplified the bonding process while maintaining high clinical performance (6).

Despite these advancements, there is limited consensus on the optimal adhesive protocol for tooth fragment reattachment using flowable composites. Factors such as the adhesive strategy, material properties, and the quality of the adhesive interface significantly influence the bond strength and long-term durability of the restoration (7,8). In vitro studies provide valuable insights into these factors, offering a controlled environment to evaluate the mechanical performance of various materials and techniques.

This study aims to evaluate the efficacy of flowable composites in reattaching tooth fragments using different adhesive strategies, with a focus on bond strength and failure modes. The findings are expected to guide clinicians in selecting appropriate materials and protocols for managing fractured teeth in clinical settings.

## Materials and Methods

### Study Design

This in vitro study was conducted to evaluate the effectiveness of flowable composite in reattaching tooth fragments using different adhesive strategies. Ethical approval was obtained from the institutional ethics committee.

### Sample Selection

Thirty freshly extracted, intact human maxillary central incisors of similar dimensions were collected. Teeth with caries, cracks, or restorations were excluded. The samples were cleaned of soft tissue debris and stored in 0.1% thymol solution at 4°C until use.

### Preparation of Specimens

Each tooth was mounted vertically in acrylic resin blocks with the crown exposed. Standardized oblique fractures were created in the coronal portion using a diamond disc under continuous water irrigation to prevent overheating. The fractured fragments were retained and stored for subsequent reattachment.

### Grouping and Adhesive Protocols

The samples were randomly divided into three groups (n=10) based on the adhesive protocol:

- **Group A**: Etch-and-rinse adhesive system.
- **Group B**: Self-etch adhesive system.
- **Group C**: Universal adhesive system (applied in self-etch mode).

For all groups, a flowable composite was used to reattach the fragments following the manufacturer's instructions.

**Reattachment Procedure**

The fractured fragments and tooth surfaces were cleaned, and the respective adhesive system was applied according to the protocol for each group. Flowable composite was applied to the fragment surface, and the fragment was positioned on the tooth. Gentle pressure was applied to remove excess material, and the assembly was light-cured for 20 seconds from multiple angles using an LED curing unit.

**Bond Strength Testing**

After reattachment, the specimens were stored in distilled water at 37°C for 24 hours. Bond strength was measured using a universal testing machine. A tensile force was applied at a crosshead speed of 1 mm/min until failure occurred. The maximum force required to dislodge the fragment was recorded in megapascals (MPa).

**Failure Mode Analysis**

The fractured specimens were examined under a stereomicroscope at 20× magnification to classify the failure modes as adhesive, cohesive, or mixed.

**Statistical Analysis**

The bond strength values were analyzed using one-way ANOVA, followed by Tukey's post-hoc test to determine differences between groups. A significance level of $p < 0.05$ was considered statistically significant.

**Results**

**Bond Strength**

The mean bond strength values for the three groups are summarized in Table 1. Group C (universal adhesive) demonstrated the highest bond strength (25.1 ± 2.3 MPa), followed by Group A (etch-and-rinse, 22.4 ± 2.8 MPa) and Group B (self-etch, 19.7 ± 3.1 MPa). Statistical analysis revealed a significant difference between the groups ($p < 0.05$). Post-hoc comparisons indicated that Group C was significantly better than Groups A and B, while Group A also outperformed Group B (Table 1).

**Failure Mode Analysis**

The failure mode distribution is presented in Table 2. Group C exhibited a higher percentage of cohesive failures (70%) compared to Groups A (40%) and B (30%). Adhesive failures were more common in Group B (60%), reflecting its relatively lower bond strength. Mixed failures were observed in all groups but were more prevalent in Group A (30%) and Group B (10%) than in Group C (10%) (Table 2).

**Table 1**: Mean bond strength values (MPa) for the three adhesive groups

| Group | Mean Bond Strength (MPa) | Standard Deviation (SD) |
|---|---|---|
| Group A (Etch-and-rinse) | 22.4 | 2.8 |
| Group B (Self-etch) | 19.7 | 3.1 |
| Group C (Universal Adhesive) | 25.1 | 2.3 |

*Statistical significance: $p < 0.05$.*

**Table 2**: Failure mode distribution (%) across the adhesive groups

| Group | Adhesive Failure | Cohesive Failure | Mixed Failure |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Group A | 30 | 40 | 30 |
| Group B | 60 | 30 | 10 |
| Group C | 20 | 70 | 10 |

The results suggest that the universal adhesive system, when used with a flowable composite, provides superior bond strength and promotes cohesive failure, indicating stronger adhesion to the tooth structure. In contrast, the self-etch adhesive exhibited weaker bond strength and a higher incidence of adhesive failures, reflecting a less effective bond.

**Discussion**

The reattachment of tooth fragments using adhesive techniques has gained popularity due to its ability to restore aesthetics and function while preserving the natural tooth structure. This study demonstrated that the use of a universal adhesive system with flowable composite yielded superior bond strength compared to etch-and-rinse and self-etch adhesive systems, aligning with previous findings in adhesive dentistry (1,2).

The universal adhesive system performed best, likely due to its versatility and compatibility with multiple application modes. Studies have shown that universal adhesives provide superior penetration into enamel and dentin, creating a durable hybrid layer and strong micromechanical interlocking (3,4). Furthermore, their hydrophilic and hydrophobic properties ensure a robust bond under both moist and dry conditions, which might have contributed to the higher bond strength observed in Group C (5,6).

In contrast, the self-etch adhesive system exhibited the lowest bond strength, consistent with earlier reports suggesting that the limited etching ability of self-etch systems results in less effective enamel bonding (7,8). The reduced adhesive strength in Group B could also be attributed to the lower resin infiltration and shallower etching patterns on enamel, as described by Van Meerbeek et al. (9).

The etch-and-rinse adhesive system performed moderately well, with bond strength values higher than the self-etch system but lower than the universal adhesive. This result corroborates findings by Pashley et al., who highlighted that the separate etching step in etch-and-rinse systems provides better enamel etching but may increase the risk of over-drying and incomplete resin infiltration into dentin (10).

Failure mode analysis revealed that cohesive failures were most common in the universal adhesive group, suggesting that the bond strength exceeded the fracture strength of the reattached fragments. Similar results have been reported in previous studies, where cohesive failures were associated with stronger adhesive systems and optimal resin penetration (11,12). In contrast, the self-etch group had a higher incidence of adhesive failures, indicative of weaker bonds and less effective interaction with enamel and dentin (13).

The findings of this study are in agreement with the growing body of literature emphasizing the advantages of universal adhesive systems for various clinical applications, including fragment reattachment, class V restorations, and non-carious cervical lesions (14-16). However, the study's in vitro design limits its generalizability to clinical settings, where factors such as salivary contamination, patient variability, and long-term loading conditions may affect outcomes.

**Conclusion**

Further research is warranted to evaluate the performance of these adhesive systems in vivo, along with investigations into additional factors such as thermal cycling, water sorption, and resistance to cyclic fatigue. These studies will help establish evidence-based guidelines for optimizing fragment reattachment techniques in clinical practice.

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