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Fracture Resistance of Reattached Incisal Fragments with Three Different Tooth Preparation Techniques: An In Vitro Study

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Abstract

Context: In today's era of evident-based minimally invasive dentistry, reattachment of the fractured crown fragment of a traumatized anterior tooth has become the most favourable treatment option.

Aim: The aim of this in-vitro study was to compare and evaluate the fracture resistance of sound maxillary incisor teeth reattached using different tooth preparation techniques, namely, circumferential chamfer, vertical groove with fibre reinforced composite (FRC) post and internal dentin groove.

Material and Methods: Sixty sound permanent maxillary incisors were mounted in acrylic blocks and divided randomly into four groups (n = 15). In Group A, 15 teeth were retained as positive control in normal saline. The remaining three groups where fragment was to be reattached, a standardized section was prepared through the middle third of crown, perpendicular to long axis of tooth with a water-cooled low speed diamond disc to simulate Ellis and Davey Class II fracture. In Group B, subsequent to reattachment with composite, a 1 mm deep circumferential chamfer was prepared on the fracture line using a diamond bur and restored with composite. In Group C, two vertical grooves 1 mm deep, 1 mm wide, and 4 mm in length were prepared on the labial surface perpendicular to the fracture line. Two fibre-reinforced composite (FRC) posts were placed in the grooves and restored with composite. In Group D, dentin was removed from the fractured fragment, filled with composite and reattached.

An onscreen calibration tool of the universal testing machine was used to record the force required to fracture the reattached fragment and the fractured specimens were examined under stereomicroscope.

Statistical analysis: One-way ANOVA was used for comparison of three groups (p value <0.05 is considered significant). For the multiple comparison, Tukey's Post Hoc test was used (p value <0.05 is considered significant).

Results: Teeth in Groups B, C, and D required lesser force to fracture when compared to the teeth in Group A.

Conclusions: The reattachment techniques used in this study resulted in fracture resistance lower to that of intact teeth; vertical grooves with fibre reinforced composite (FRC) post showed superior result compared to the other techniques.

Key Messages: Recent developments in restorative materials, adhesive protocols and preparation designs have allowed clinicians to predictably reinstate fractured teeth. With the advent of adhesive dentistry, reattachment using the patient's own tooth fragment has become a simplified and more reliable treatment option.

Keywords
Dental trauma; Fibre-reinforced composite post; Fragment reattachment; Permanent tooth.

Introduction

The prevalence of maxillary central incisor teeth being injured in any trauma to the facial region is 37%, attributable to their anterior placement in the arch and protrusive eruptive pattern, followed by maxillary lateral incisors (16%) and mandibular central incisors [1]. Most common form of traumatic dental injuries are the crown fractures of permanent dentition. One of the greatest challenges to a dentist is the aesthetic rehabilitation of fractured anterior teeth [2].

Following trauma immediate replacement of lost tooth structure is desired and reattachment of fractured teeth segments is one such treatment option. Improvement in adhesive techniques and restorative materials has made reattachment of dental fragment possible [3]. Reattachment procedures have better prognosis with promising long-term consequences due to the current notions of dentine hybridization. Incisal function, natural translucency and surface texture are reinstated by reattachment. It also provides superior aesthetics, favourable emotional and social response and is relatively simple, atraumatic, and inexpensive procedure [4]. Fragment reattachment is a provisional recuperative technique with a durability of 2-7 years as stated by the IADT guidelines (2020) [5]. The preparation method and the material used for bonding have substantial effects on the strength of such refurbished teeth [6].

The aim of this in-vitro study was to evaluate and compare the fracture resistance of reattached incisal fragments of sound maxillary incisor teeth using three different tooth preparation designs: circumferential chamfer, vertical grooves with fibre reinforced composite (FRC) posts and internal dentin groove.

Materials and Methods

Sixty human non-carious freshly extracted permanent maxillary central incisors were collected. The teeth were meticulously cleaned free of debris and calculus using scalers and stored in normal saline at room temperature. The samples were randomly divided into four groups (n=15) and embedded in standardized jigs using self-cure acrylic till the level of cement enamel junction parallel to long axis of the jig.

Sample Preparation

In Group A15 teeth were kept as positive control in normal saline. A water-cooled low speed diamond disc was used to simulate the Ellis and Davey Class II fracture, cutting through the middle third of the crown perpendicular to the long axis of the tooth in the remaining three groups.

Sample Restoration

Group A: Positive control group. The intact teeth were not sectioned.

Group B: Fractured fragment was reattached using Single Bond Universal adhesive (3M ESPE, St. Paul, MN, USA) and Filtek Z350 XT Universal Restorative body shade (3M ESPE, St. Paul, MN, USA)and cured in stages.

A 1 mm deep circumferential chamfer was prepared on the fracture line using a diamond bur with depth marker and restored with the same composite.

Group C: Following reattachment, two vertical grooves, 1mm deep, 1mm wide and 4mm in length were prepared on the labial surface perpendicular to fracture line using high-speed depth orientation diamond bur. After applying the adhesive, two 4 mm length FRC posts were placed in the grooves. The space between the FRC post and surface of the tooth was restored with composite and light-cured.

Group D: The entire dentin portion of the fragment was removed using high-speed airotor diamond bur. After application of the adhesive, the area where the dentin was removed was filled with dental composite, reattached, and cured.

Evaluation

The specimens were mounted in the universal testing machine (Tecsol-TSI-BDS) (Figure 2A) at 45° to the horizontal plane, and the load was applied in the labial to lingual direction at 1mm/min in the centre of the restoration using a reinforced stainless-steel wedge (Figure 1, 2B). The force required to fracture the tooth was recorded using an onscreen calibration tool (Figure 2C).

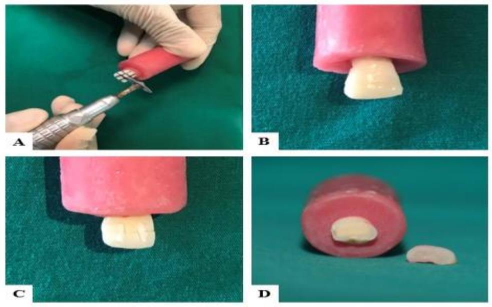

Figure 1: Methodology A) Sectioning the sample, B) Circumferential Chamfer Technique, C) Vertical Grooves with Fiber Reinforced Composite Post Technique, D) Internal Dentin Groove Technique.

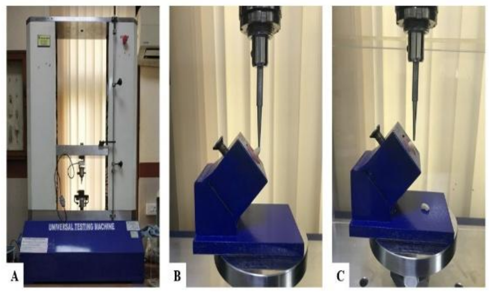

Figure 2: A) Universal Testing Machine, **B)** Load applied on the mounted sample, **C)** Fractured sample.

Stereomicroscopic Evaluation for Mode of Fracture

The samples were analysed for mode of fracture under stereomicroscope (Stemi DV4: Carl Zeiss, Gottingen, Germany) at 3.5x magnification and was categorized as one of the two characteristic failure modes: adhesive fracture at tooth-restoration interface and cohesive breakage of the remaining part of the tooth (Figure 3).

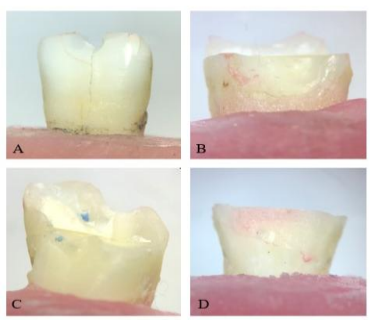

Figure 3: Stereomicroscopic evaluation for mode of fracture **A)** Intact, **B)** Circumferential Chamfer, **C)** Vertical Grooves with FRC Posts and **D)** Internal Dentin Groove.

Results

The data were collected, tabulated, and subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 23 (IBM, Chicago, US). One-way ANOVA was used for comparison of three groups (p value <0.05 is considered significant). Continuous variable was described in terms of mean and standard deviation. For the multiple comparison of groups, Tukey's Post Hoc test was used (p value

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<0.05 is considered significant). When compared to group A, all the teeth in Groups B, C, and D required lesser force to fracture as shown in Table 1.

Groups	M (SD)	F	p value	95% CI
Intact	41.20 (9.20)	56.0	0.00	36.11 to 46.30
Circumferential Chamfer	28.48 (10.15)			22.86 to 34.11
Vertical Grooves with FRC Posts	39.70 (4.47)			37.22 to 42.18
Internal Dentin Groove	10.17 (3.43)			8.27 to 12.07

Table 1: Comparison of shear bond strength for the four groups.

Table 2 gives the intergroup comparison which revealed that the force needed to fracture the teeth in Group B and Group D was significantly lesser to the force required to fracture the teeth in Group A (P<0.05), but not when compared with Group C (P=0.945).

Groups		P value	95% CI
Intact	Circumferential Chamfer	0.000	5.55 to 19.88
	Vertical Grooves With FRC Posts	0.945	-5.66 to 8.66
	Internal Dentin Groove	0.000	23.86 to 38.19
Circumferential Chamfer	Vertical Grooves With FRC Posts	0.001	-18.38 to -4.05
	Internal Dentin Groove	0.000	11.14 to 25.48
Vertical Grooves With FRC Posts	Internal Dentin Groove	0.000	22.36 to 36.69

Table 2: Multiple comparison using Tukey post hoc test.

Groups	Adhesive fracture at tooth-restoration interface.	Cohesive breakage of the remaining part of the tooth.
Circumferential Chamfer	8	7
Vertical Grooves With FRC Posts	11	4
Internal Dentin Groove	13	2

Table 3: Evaluation of mode of fracture among the prepared groups.

The most common type of fracture mode was adhesive fracture at tooth–restoration interface and cohesive breakage of the remaining part of the tooth as observed in stereomicroscopic evaluation (Table 3).

Discussion

Uncomplicated crown fractures involving only enamel and dentin are common in children [7]. Direct composite restorations, laminate veneers, jacket crowns and post and core are substitutes for re-establishing the fractured teeth, but one of the finest methods to restore the function and aesthetics is its reattachment [8]. This method maintains the natural characteristics of wear, shape, surface texture and colour and produces minimal tooth loss [9].

Additional preparation of the fragment or tooth shows a better performance for resistance to fracture as concluded by many studies. Preparation techniques such as enamel bevelling of the fragment and remaining crown, internal dentin groove, external chamfer, and the over contour technique are some of them. It has turned out to be ostensible that the preparation method and material used to join fractured fragments have noteworthy impact on the fracture strength of restored teeth [10].

A simple reattachment with no preparation of the fragment or tooth could restore only 37.1% of the intact tooth's fracture resistance as concluded by Reis et al. 60.6% was the recovery of a buccal chamfer and an over contour and placement of an internal groove recovered of 97.2 and 90.5% fracture strength [11].

Other studies have also shown that a preparation post reattachment, such as a bevel or a chamfer, has a positive effect on fracture resistance.12In a recent study, Stellini et al. fractured cattle incisors and repaired them with different preparations post reattachment. He concluded that the over contouring or the combination of vestibular and lingual chamfer gave the tooth a fracture resistance 50% superior to that of an intact tooth [13].

Fragment hydration is an important feature for the finest prediction for attachment of the fragment to the residual tooth since it indorses superior bond strength than with dehydrated fragments [14]. In a study on bovine teeth, Poubel et al. stated that the fracture strength following reattachment of a dehydrated fragment was inferior to that of a tooth kept hydrated or rehydrated for 15 minutes [15].

A study conducted by Badami et al. concluded that the resistance of the fracture segment could be directly proportional to the surface area of adhesion [16]. In the preparation techniques the quantity of dentin reduced in internal dentin groove and circumferential chamfer groups was standardized using a diamond disc bur of diameter 4mm to reduce operative error.

Many previous attempts that have been directed toward improving the fracture strength of the rebonded fragment as the main reason of failure of the reattached tooth fragment is fresh trauma or extreme masticatory forces [17]. The development of adhesive systems has encouraged many clinicians to employ only these systems for reattachment of the fractured fragments. Adhesives with phosphoric acid as an isolated conditioner characterize the gold standard of dependable and robust enamel attachment despite the ever-increasing popularity of self-etching bonding agents [18].

In the present study, the reattachment done with vertical grooves with fibre Reinforced Composite (FRC) posts showed good fracture resistance when compared to circumferential chamfer and internal dentin groove. The frequently involved adhesive type of fracture involved the enamel-resin interface and cohesive fracture inside the body of resin. Great quantity of force was applied but there was no breakage inside vertical posts, it triggered the rupture of reattached fragment parting the posts unbroken.

The superior bond strength and fracture resistance recovery of vertical grooves with Fibre Reinforced Composite (FRC) posts may be adopted to improve the longevity of reattached teeth. From a clinical standpoint, the use of this fragment reattachment technique is in accordance with the minimal intervention concept. It reduces to the minimum the quantity of enamel and dentin lost and guarantees a complete restoration of the tooth.

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