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Comparative evaluation of fracture resistance of reattached anterior tooth fragment using different re-attachment techniques: an in vitro study.

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Abstract : Uncomplicated crown fractures, affecting only enamel and dentin, are common in children, representing 28%-44% of dental traumas. Treatment focuses on restoring esthetics and function, with options like composite restorations or fragment reattachment. Reattaching a viable tooth fragment is favored for preserving natural appearance and wear characteristics. Advances in adhesive dentistry have enhanced reattachment predictability, offering superior esthetics and conservation of tooth structure. This study evaluates the fracture resistance of various reattachment techniques using nanohybrid composite resin. The study included 30 sound, caries-free maxillary central incisors, sectioned to simulate uncomplicated fractures. Specimens were divided into three groups based on reattachment techniques: internal dentinal groove, enamel bevel, and modified saucerization. Restorations involved etching, adhesive application, and nanohybrid composite resin buildup, followed by light curing. Fracture resistance was tested using a Universal Testing Machine. The results of our study indicated that the modified saucerization technique exhibited the highest fracture resistance, with a mean value of 27.92 ± 2.32 KgF. This was followed by the internal dentinal groove group, which had a mean fracture resistance of 21.72 ± 1.99 KgF. The enamel bevel group demonstrated the lowest fracture resistance, with a mean of 12.94 ± 2.20 KgF. The differences in fracture resistance among the three groups were statistically highly significant ($p < 0.001$), indicating the superior performance of the modified saucerization technique in reinforcing reattached fragments. The findings suggest that modified saucerization provides the best reinforcement due to its enhanced bonding area and force distribution, while the enamel bevel technique may be less effective due to potential misalignment and reduced bonding strength. To validate these results and optimize clinical outcomes, further clinical trials are necessary.

***IndexTerms* - Enamel bevelling, fracture reattachment, internal dentinal groove, nanohybrid composite resin, modified saucerization, uncomplicated coronal fracture**

Introduction:

Uncomplicated crown fractures, which involve only the enamel and dentin, are prevalent among children, accounting for approximately 28%-44% of all dental traumas in this age group.[1,2] The primary goal of restorative planning for these injuries is to restore the patient's esthetics and functionality. Rehabilitation methods can range from composite resin restorations to the more conservative approach of dental fragment bonding. The success of fragment reattachment depends on the viability of the tooth fragment and its adaptability to the remaining tooth structure, which directly impacts the overall prognosis. This technique has been widely reported as satisfactory or very satisfactory by patients, parents, or legal guardians[3], as it maintains the tooth's natural appearance, including form, contour, alignment, translucence, surface texture, and positioning.[4-6]

Advancements in restorative materials, placement techniques, preparation designs, and adhesive protocols have significantly improved the predictability of restoring fractured teeth. The advent of adhesive dentistry has simplified the fragment reattachment process, making it more reliable by allowing clinicians to use the patient's original tooth fragment to restore the damaged tooth. Tooth fragment reattachment offers distinct advantages over conventional restorative techniques. The most notable benefit is the ability to preserve the original tooth's esthetics, including its shape, color, brightness, and surface texture. Unlike other restorations, the reattached incisal edges tend to wear at a rate similar to that of the adjacent natural teeth, ensuring a harmonious appearance over time. This technique can also be less time-consuming and provides more predictable long-term outcomes compared to traditional restorations.[5]

The techniques for reattaching tooth fragments vary, with some studies recommending additional preparation of the remaining tooth or the fragment, such as creating dentin grooves, chamfers, or bevels to enhance bonding. However, other studies advocate for a no-preparation approach, emphasizing a simpler and more conservative procedure. The choice of adhesive systems and intermediate materials also plays a crucial role in the success of the reattachment. Adhesive systems can be categorized into multimode, total-etch, or self-etch types, each requiring different application protocols. Intermediate bonding materials range from conventional composite resin to flowable composite resin, resin cement, or glass ionomer cement. [6,7]

The lack of consensus on the optimal combination of techniques and materials highlights the need for continued research to determine the best approach for achieving long-term bond strength between the tooth fragment and dentin. Reis et al. emphasized that the combination of materials used is as critical as any prior preparation when evaluating fracture resistance, suggesting that both aspects must be carefully considered to optimize outcomes.[8]

Fragment reattachment is a practical and conservative treatment option for coronal fractures of anterior teeth, particularly in pediatric patients. It offers a straightforward and minimally invasive alternative to composite resin restorations, ensuring satisfactory retention, esthetics, and complete restitution of the tooth's integrity.[9]

Despite the wide range of techniques available, there remains no universal agreement on the best method to enhance the bond strength and longevity of the reattachment. Therefore, this study aims to evaluate and compare the fracture resistance of reattached anterior tooth fragments using different reattachment techniques.

Methodology:

The study was conducted after obtaining ethical approval from Institutional Ethical Committee. The sample size was calculated using the G*Power Version 3.0.1 (Franz Faul Universitat, Kiel , Germany); with the power of the study 80% and confidence limit of 95% which was derived to be 10 each group. The study included 30 sound, caries-free human maxillary central incisors extracted for therapeutic reasons, ensuring that the teeth were free from any structural damage or decay. Following extraction, the teeth were immediately washed under running tap water to remove blood and debris and cleaned of any attached soft tissues. To preserve their structural integrity, the teeth were stored in distilled water until further use, in compliance with Occupational Safety and Health Administration (OSHA) guidelines.

The roots and part of the crown, extending up to 1 mm above the cemento-enamel junction, were placed in a cylindrical mold with an internal diameter of 15 mm and filled with acrylic resin to secure the specimens. This process ensured that only the necessary portion of the tooth was exposed for further procedures, while the rest remained stable and fixed within the resin. Either the mesio-incisal or disto-incisal part of each tooth was cut at a distance of 3 mm from the incisal edge to simulate an uncomplicated class II Ellis fracture. These precise cuts were made using a diamond disc attached to a micromotor straight handpiece, ensuring consistency and accuracy in the fracture simulation. Following the cutting procedure, the teeth and their corresponding fragments were carefully preserved in a 0.9% saline solution to maintain hydration and prevent desiccation until the restoration procedures were performed.

The study groups were as follows:

Group I: Reattachment of fractured fragment using internal dentinal groove preparation with Nanohybrid composite.

Group II: Reattachment of fractured fragment using enamel bevel technique with Nanohybrid composite

Group III: Reattachment of fractured fragment using modified saucerization technique using Nanohybrid composite

Restoration of Experimental Groups:

Group I: Before reattachment, an internal dentinal groove measuring 1 mm in depth and width was created within the fragment and the remaining tooth using a flat-end cylindrical diamond bur (SS White SF41, FG 835010, Wadhwan, Gujarat, India) attached to a high-speed handpiece. Both the tooth and the fragment were etched with 37% phosphoric acid for 15 seconds according to the manufacturer's instructions. After rinsing and gently drying while keeping the dentin moist, a dentine adhesive system (AdperTM Scotchbond Multipurpose, 3M ESPE India Ltd.) was applied. Nano-hybrid composite was then applied over the conditioned surfaces and within the internal groove. The coronal fragment was positioned onto the remaining tooth structure and reattached with finger pressure, with excess material removed before polymerization. The composite was light-cured for 40 seconds on both buccal and palatal surfaces.

Group II: A 45-degree bevel, extending 1.5 mm on the buccal surface, was prepared using a tapered fissure diamond finishing bur (SS White, FG 850F016) attached to a high-speed handpiece with air-water cooling. Both the tooth and the fragment were etched with 37% phosphoric acid (Eco-etch, Ivoclar Vivadent) for 15 seconds, as instructed by the manufacturer. After rinsing and gentle drying, the dentin was kept moist, and a dentine adhesive system (Te-Econom Bond, Ivoclar Vivadent) was applied. The restoration was completed with nano-hybrid composite (Tetric EvoCeram, Ivoclar Vivadent) using an incremental technique of 3 to 4 layers. Each layer was light-cured for 40 seconds on all surfaces: buccal, palatal, mesial, and distal. The restorations were finished and polished with flexible polishing discs 24 hours after the procedure.

Group III: Saucerization of the fracture line on the buccal surface was performed using a small round diamond bur (1.4 mm diameter) with a high-speed handpiece under air-water cooling. Both the tooth and the fragment were etched with 37% phosphoric acid (Eco-etch, Ivoclar Vivadent) for 15 seconds, following the manufacturer's instructions. After rinsing and gentle drying, while keeping the dentin moist, the dentine adhesive system (Te-Econom Bond, Ivoclar Vivadent) was applied. Nano-hybrid composite (Tetric EvoCeram, Ivoclar Vivadent) was built up incrementally, with 3 to 4 layers, each light-cured for 40 seconds on the buccal and palatal surfaces using a light-curing machine (Hilux 200, Heraeus Kulzer, intensity of 400 mW/cm^2). The restorations were finished and polished with flexible discs (Sof-Lex Pop On polishing disks, 3M dental products, St. Paul, MN) 24 hours after restoration.

Following reattachment, the specimens were mounted on a custom-made fixture and stored in saline to prevent dehydration, which could affect the microhardness of the teeth. A perpendicular load was applied at a 90° angle to the bonded area in a buccal-to-lingual direction using a 2 mm diameter stainless steel ball connected to a jig in a Universal Testing Machine (Instron 3345, Model No. 2519-07) at a cross-head speed of 1 mm/min. The force required to fracture each tooth was recorded in KgF.

Results:

The data obtained were tabulated and statistically analyzed using ANOVA and Tukey's post hoc test performed by using IBM Statistical Package for Social Sciences (Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) considering $p<0.05$ as statistically significant. The failure modes of each specimen were visually assessed and categorized as adhesive failure (failure at the tooth-resin interface), cohesive failure (failure within the resin or below the cemento-enamel junction), or mixed failure.

Table 1 shows that the mean fracture resistance was highest in the Modified Saucerization group, with a mean value of 27.92 and a standard deviation of 2.32. The Internal Dentinal Groove group demonstrated moderate fracture resistance, with a mean of 21.72 and a standard deviation of 1.99. The Enamel Bevel group had the lowest fracture resistance, with a mean of 12.94 and a standard deviation of 2.20. Analysis by One way ANOVA showed that the difference between the three groups was statistically highly significant. Table 2 shows that Tukey's post –hoc analysis depicted that difference between Internal dentinal groove vs Enamel bevel, Internal dentinal groove vs Modified Saucerization and Enamel bevel vs Modified Saucerization were statistically highly significant ($p<0.001$).

Discussion:

Dental trauma is a major public health concern due to its high prevalence, significant impact on economic productivity, and the overall quality of life of affected individuals. Such injuries can result in pain, functional impairment, psychological distress, and long-term dental complications, all of which contribute to a considerable burden on healthcare systems and society.[10] Epidemiological studies have highlighted that the incidence of fractured teeth shows considerable variability across different populations, influenced by factors such as age, sex, and the fracture classification system used in assessments.[10]

Fracture reattachment is increasingly recognized as a preferred treatment modality for managing fractured teeth, particularly in cases where the tooth fragment is available and in good condition. This technique involves bonding the fractured segment back to the remaining tooth structure, offering a conservative approach that preserves the natural tooth and avoids more invasive procedures like composite restoration or full coverage crowns. This provides a reliable, efficient, and patient-friendly solution that meets both functional and aesthetic demands while minimizing costs and treatment duration. This makes it a highly attractive option, especially for younger patients or those seeking to maintain their natural tooth appearance with minimal intervention.[11]

Nanocomposites are characterized by a high volume of nanometric filler particles dispersed within the resin matrix. This high filler content is responsible for the enhanced physical, chemical, and biological properties of these materials. As a result, nanocomposites offer superior strength, better wear resistance, and improved aesthetic qualities compared to traditional composite resins.[12] The advanced properties of nanocomposites make them highly suitable for various dental applications, providing a more durable and visually appealing restoration that closely mimics the natural tooth structure.[13]

Our study found that the internal dentinal groove design demonstrated a statistically highly significant increase in fracture resistance compared to the enamel bevel design, which had the lowest fracture resistance among the three designs tested. There is a lack of data in the literature for direct comparisons among these three techniques, making it difficult to perform a direct comparison. The likely reason for the modified saucerization technique demonstrating higher values compared to other two lies in the reinforcement provided by the chamfer preparation adjacent to the fracture line, followed by restoration with resin composite. This approach involves the removal of the aprismatic superficial enamel layer, which is typically richer in fluoride content. The elimination of this layer enhances the acid etching process and increases the free surface energy, which, in turn, improves surface wetting and enlarges the surface area of the exposed enamel. These changes contribute to better material retention and a more stable bond between the tooth and the restorative material.[14]

The extension of the material over a larger surface area allows for more effective force distribution across the enamel, thereby enhancing the overall toughness of the resin composite placed on the labial surface. This increased toughness enables the composite to absorb greater fracturing loads applied to the tooth, potentially delaying or preventing failure. Moreover, this method yields a superior marginal seal and enhanced esthetic results, making the interface between the tooth and the restoration difficult to detect.[15]

Study by Bruschi-Alonso RC et al (2010) stated that the use of a circumferential chamfer combined with the Single Bond adhesive system can closely match the immediate impact strength of restored teeth to that of intact, sound teeth.[5]

The findings of our study depict that internal dentinal groove design showed statistically highly significant higher fracture resistance as compared to enamel bevel design which was the least among the three tested techniques. The enhanced fracture resistance observed can be attributed to the utilization of a greater volume of resin, which forms a continuous, intact bar within the restoration. This continuous bar structure acts to counteract the forces applied to the labial surface of the tooth. By creating a cohesive barrier, the resin not only provides a cushioning effect but also effectively distributes the forces acting on it, thereby enhancing the overall durability and resistance to fracture.[14]

Additionally, the preparation of a groove within the dentin of both the tooth fragment and the tooth itself plays a crucial role. This groove is strategically placed to ensure a strong, integrated connection between the restorative material and the tooth structure while preserving a sufficient amount of dentin to protect the pulp. The groove's design helps to further stabilize the restoration by anchoring the resin within the tooth, which contributes to the improved mechanical performance of the restoration under stress. This careful preparation ensures that the structural integrity of the tooth is maintained, offering a robust and durable solution against fracturing forces.[14]

The results are similar to study conducted by Reis A et al. (2001)[17] who concluded that incorporating an internal dentinal groove can achieve fracture strength comparable to that of sound teeth. Similarly, Esin Pusman et al. (2010)[18] found that the highest recovery of fracture strength was achieved with the internal dentinal groove technique, followed by the over-contour and simple reattachment techniques.

The least favourable results were obtained with enamel bevel technique. A practical drawback of preparing the enamel groove prior to reattachment is that it can result in an imperfect fit of the fragment, thereby reducing the accuracy of the reattachment. This misalignment may negatively impact the long-term durability and aesthetic quality of the reattached tooth as the composite band on the labial surface becomes discolored with time, underscoring the critical importance of selecting the appropriate technique in restorative procedures.[16]

Several factors can influence the fracture resistance of a reattached tooth in in vitro studies, potentially affecting the outcomes and their comparability. These factors include the type of teeth selected, as variations in tooth anatomy and structure can lead to differences in how the teeth respond to reattachment procedures. The choice of root embedment material also plays a crucial role, as it affects the stability and support provided to the tooth during testing.[19] Similarly, the selection of storage media and the duration for which the teeth are stored can impact the tooth's moisture content and integrity, thereby influencing the results.[20]

The mode of fracture, whether it is controlled or mimics natural fractures, can alter the fracture resistance observed. The presence of a smear layer, which can interfere with bonding, and the acid etching pattern used to prepare the tooth surface also significantly affect the strength of the reattachment.[21] The choice of dentin bonding agent, which varies in composition and bonding strength, along with the method and extent of composite polymerization, further contributes to differences in fracture resistance.[2,5] Lastly, the amount of load applied to fracture the reattached fragments can skew results if not standardized, highlighting the importance of consistency in testing protocols to ensure reliable and comparable data.[4]

The study identifies significant limitations affecting the external validity of its findings. Key issues include the loss of tooth structure during sectioning with a diamond disk, the inability to replicate the speed of repeated trauma occurring in vivo, and challenges in simulating actual intraoral forces in a laboratory setting. These factors may lead to discrepancies between laboratory results and real-world clinical scenarios. To address these limitations, clinical trials are necessary to validate the hypotheses proposed by laboratory research, ensuring that findings are applicable and relevant in clinical practice, ultimately enhancing patient care and treatment outcomes.

Tables:

Table 1: Comparison of fracture resistance between three groups:

Group	Fracture resistance (Kg/F)		F value, p value
	Mean	Standard Deviation	
Internal dentinal groove	21.72	1.99	F=120.148, p<0.001*
Enamel bevel	12.94	2.20	
Modified Saucerization	27.92	2.32	

*statistically highly significant

Table 2: Post-hoc inter-group comparison between the three groups:

Group	p value
Internal dentinal groove vs Enamel bevel	<0.001*
Internal dentinal groove vs Modified Saucerization	<0.001*
Enamel bevel vs Modified Saucerization	<0.001*

*statistically highly significant

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