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Dentistry Section

Comparative Evaluation of Fragment Reattachment and Fracture Resistance of Tooth Stored in Different Hydration Media when Reattached with Different Materials: An In-vitro Study

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ABSTRACT

Introduction: Different methods have been developed to restore an uncomplicated crown fracture, varying from less invasive procedures to aesthetic restorations. Fragment reattachment has been established as a better alternative for restoring aesthetics, anatomy, and improved function. The rationale of the study lies in the fact that the materials used in the study are readily available and has proved beneficial in many literatures.

Aim: To compare the tooth reattachment success and fracture resistance between tooth remnant and reattached part using different reattachment materials when the fragments were in different storage conditions.

Materials and Methods: The present in-vitro, experimental study was conducted at Guru Nanak Institute of Dental and Research, Panihati, West Bengal, India, Indian Institute of Engineering Science and Technology, Shibpur and Narula Institute of Technology, Agarpara for one and half years, July 2022 to December 2023. A total of 96 Maxillary permanent central incisors extracted due to periodontal problems with approximately similar dimensions, mesiodistal width at the junction of middle and incisal third approximately between 8.4 to 8.7 mm were included in the study. Sample was divided into four groups: 1 positive control (A) and 3 experimental, based on storage media (B- Normal Saline, C- Fat-free milk, D- Stored Dry). Each experimental group was further subdivided into three sub-groups according to the different reattachment material (1- Light cure GIC; 2- Nano-filled packable Composite; 3- Flowable Composite). Tooth fracture was simulated and then the fracture fragments were stored as per the standard rehydration protocol for each group and reattached accordingly. The samples were then mounted on a Universal Testing Machine (UTM) to evaluate fracture resistance. The tooth reattachment success was noted by calculating the distance between the reattached tooth fragment from the reattachment material using Scanning Electron Microscopy. One-way Analysis of Variance (ANOVA) and Tuckey's post-hoc tests were used for intergroup and intragroup comparisons. The level of significance was fixed at p=0.05 and any value ≤0.05 was considered to be statistically significant.

Results: It was seen that significant differences were seen in fracture resistance based on different storage media and different reattachment materials. Among the samples, it was found that the fracture resistance is the highest in packable composite in the fat-free milk media with a mean value of 278.09 (SD 9.54). Also, it was found that distance between restoration and tooth surface is the smallest in packable composite in the fat-free media with a mean value of 1.4131 μm (SD 0.12880). These differences were statistically significant.

Conclusion: The success of reattachment of a fractured anterior tooth with its fractured fragment was affected greatly by the rehydration of the fragments and also by the type of reattachment material used.

Keywords: Bonding material, Fragment bonding, Storage media, Tooth crown injury, Uncomplicated crown fracture

INTRODUCTION

In children and young adults, Traumatic Dental Injuries (TDI) is common. It accounts for five percent of all injuries [1]. Research indicates that 25% of school children suffer from dental trauma, and 33% of individuals with permanent dentition have had trauma, with the majority of injuries happening before the age of 19 [2,3]. Crown fractures are the most frequent TDIs for permanent teeth, while luxation injuries are the most frequent in the primary dentition. To ensure a positive outcome, proper diagnosis, treatment planning, and follow-up are crucial.

The permanent dentition has the highest frequency of TDI [4]. Complete coronary fracture involving the enamel and dentin is a frequent occurrence; the most common type of fracture being uncomplicated enamel fractures [5-7] that usually involve the maxillary incisors [6-8] followed by the maxillary lateral incisors and mandibular central incisors [9]. The position and eruption of maxillary central incisors pose a serious risk for trauma.

In 2020, Tiwari N et al., conducted a meta-analysis which found that the prevalence of TDI in the Indian community was thirteen cases per 100 people. For age groups under six, it was 15%, while for those over six, it was 12%. Falls was the most common cause of TDI with the most frequent location being home [10].

The most frequent cause of traumatic oral injuries was found to be falls (from 31.7 to 64.2%), followed by bicycle accidents (up to 19.5%), sports activities (up to 40.2%), traffic accidents, and physical aggression combined with other variables (up to 6.6%) [11-14].

Males experienced nearly twice as many TDIs as girls, according to studies [15-19]. Boys' increased involvement in contact sports, altercations, and car accidents may be the cause of these outcomes.

It is crucial to restore a cracked crown for both aesthetic and practical reasons. The length of the fracture, the patient's age, the stage of root growth, any potential pulp and periodontal involvement, any aesthetic issues, and the amount and condition of the tooth tissue that is still present should all be taken into consideration when developing a treatment plan. Different disciplines may be included in the treatment plan, necessitating a multidisciplinary approach. Additionally, its prognosis is frequently unknown and its therapy may be lengthy.

A variety of techniques, including less invasive treatments and attractive restorations such resin crowns, stainless steel crowns, orthodontic bands, and direct resin composite restorations with or without an intra-radicular retainer, have been developed to repair cracked crowns. Healthy tooth structure may be sacrificed as a result of these different treatment approaches. Composite resin was frequently used to repair fractured crowns. Composite resins' drawbacks include marginal staining, discolouration, lack of marginal integrity, and low abrasion resistance when compared to enamel.

Chosack A and Eidelman E (1964) suggested using the tooth piece itself to repair damaged crowns [20]. In addition to offering emotional and social benefits, this technique has since shown high success rates and gained popularity due to its benefits, which include aesthetic and functional recovery, minimal restorative material use, anxiety-prone parents, safety, conservatism, simplicity, speed, and lower cost. If the fragment is available, the International Association of Dental Traumatology has advised fragment reattachment as the optimum treatment for simple crown fractures of permanent teeth [21]. Because the tooth's surface texture, colour, and overall anatomic form are preserved, reattaching a fragment can result in good and long lasting aesthetics [22-24]. It is more conservative and is a reasonably simple procedure. It restores tooth function and elicits an immediate positive emotional and social response from the child.

Fragment hydration is a key component of the optimal prognosis for attachment of the fragment to the remaining tooth because it fosters a stronger bond than with dehydrated fragments [24,25]. Hydration preserves the tooth's health and natural visual appeal. The fragment's preparation and storage before it is reattached are crucial factors that affect the final clinical result.

The reattached pieces are vulnerable to refracture in the event of another stressful event or when the restored teeth are used in ways that are not physiological. As a result, the fracture strength of reattached teeth has been the main source of worry. The primary determinant is the fragmented fragment's robust, long lasting, and predictable union with the intact tooth. Therefore, the aim of this study is to compare the bonding quality and fracture resistance when the fragments are stored in different hydration media and reattached with different reattachment materials.

MATERIALS AND METHODS

The present in vitro, experimental Study was conducted at Guru Nanak Institute of Dental Sciences and Research, Panihati, Indian Institute of Engineering Science and Technology, Shibpur, Narula Institute of Technology, Agarpara, Kolkata, India. Duration of the study was one and half years, from July 2022 to December 2023. The study was conducted after Ethical Committee clearance the ethical approval no. was GNIDSR/IEC/21-24/30.

Sample size calculation: Total sample size considered was 96. The sample size was calculated using G*Power software. Considering the effect size 0.35, α err 0.05 and Power 0.80, the total sample size N=96. The selected teeth will be randomised into four groups, based on the different hydration solutions and control. Hence, in each group the sample size n=96/4=24.

Inclusion criteria: Maxillary permanent central incisors extracted due to periodontal problems and having approximately similar dimensions (M-D with at the junction of middle and incisal third approximately between 8.4 to 8.7 mm).

Exclusion criteria: Carious tooth (caries in the crown region) or presence of developmental defects or cracks.

Study Procedure

A total of 96 human non carious permanent maxillary incisors extracted for periodontal reasons were collected after ethical committee clearance. Thorough cleaning of tissue remnants was performed by means of curette and an ultrasonic scaler (mechanical prophylaxis). The teeth were sterilised using autoclave according to a study by Sandhu SV et al., and kept in a 0.9% saline solution, until the beginning of the experiment [26].

- The teeth were randomly divided into four groups of 24 teeth each- one control group where tooth fracture is not simulated but it was stored in normal saline and three experimental groups based on-
  - the different hydration solutions (P='normal saline' and Q='fat-free milk' and R='no hydration used')
  - reattachment materials (X='light cured GIC', Y='nano-filled packable composite' and Z='flowable composite') [Table/Fig-1].

Storage media		Reattachment material (n)		
A	Positive control			
B	Normal saline (N=24)	B1	B2	B3
		Light cure GIC (8)	Nano-filled packable composite (8)	Flowable composite (8)
C	Fat-free milk (N=24)	C1	C2	C3
		Light cure GIC (8)	Nano-filled packable composite (8)	Flowable composite (8)
D	Not stored in any media (N=24)	D1	D2	D3
		Light cure GIC (8)	Nano-filled packable composite (8)	Flowable composite (8)

[Table/Fig-1]: Description of storage media and reattachment materials.

Final grouping is as follows [Table/Fig-1]:

- Group-A- positive control (sound tooth)
- Group-B-
  - B1: stored in storage medium P and reattached with X;
  - B2: stored in storage medium P and reattached with Y;
  - B3: stored in storage medium P and reattached with Z.
- Group-C-
  - C1: stored in storage medium Q and reattached with X;
  - C2: stored in storage medium Q and reattached with Y;
  - C3: stored in storage medium Q and reattached with Z.
- Group-D-
  - D1: not stored in any medium and reattached with X;
  - D2: not stored in any medium and reattached with Y;
  - D3: not stored in any medium and reattached with Z.
- Tooth in each experimental group was sectioned transversely to the long axis of the tooth, 2.5 mm away from the incisal edge using a diamond disk involving the enamel and dentin [Table/Fig-2].

[Table/Fig-2]: Tooth fracture simulation.

- For groups B1, C1, and D1, light-curing glass ionomer cement (FUSION I-SEAL | Prevest DenPro) was applied to the fragmented surface of the tooth using an applicator tip. A thickness of 1 mm was retained in accordance with the manufacturer's specifications. The fragment was manipulated with tweezers, and a brush was employed to eliminate the surplus material. Subsequently, the reattached surfaces underwent light curing for 40 seconds in four intervals: 10 seconds on the mesial wall, 10 seconds on the distal wall, 10 seconds on the labial wall, and 10 seconds on the lingual wall.
- The remaining groups underwent enamel etching using a 37% phosphoric acid gel (Prime Dental Etching Gel) for 30 seconds, followed by a 30-second rinse, and a 10-second drying period. The universal adhesive (Ivoclar Vivadent Te-Econom Bond) was thereafter applied for 20 seconds. The surfaces were dried for five seconds with an air syringe to facilitate solvent evaporation. The adhesive underwent light polymerisation for 10 seconds on the mesial wall and 10 seconds on the distal wall.
- For groups B2, C2, and D2 A nano-filled packable composite (Fusion |Prevest DenPro) of shade A2 was applied to the broken tooth surface, the fragment had been adjusted with tweezers, and a brush was utilised to eliminate the surplus composite. Subsequently, the reattached surfaces underwent light curing for 40 seconds in four intervals: 10 seconds on the mesial wall, 10 seconds on the distal wall, 10 seconds on the labial wall, and 10 seconds on the lingual wall.
- For groups B3, C3, and D3, a flowable composite (Fusion Flo |Prevest DenPro) of shade B3 was applied to the fractured surface of the tooth, and the fragment was adjusted with tweezers, while a brush was utilised to eliminate the excess composite. Subsequently, the reattached surfaces underwent light curing for 40 seconds in four intervals: 10 seconds on the mesial wall, 10 seconds on the distal wall, 10 seconds on the labial wall, and 10 seconds on the lingual wall.
- Half of the reattached specimens from each group were embedded in acrylic block to stabilise the tooth for placement under the UTM (UTM- Mechanical Universal Testing Machine, Model- KUT60E, Ratnakar Enterprise) to evaluate the fracture resistance. The rod of UTM was held perpendicular to the long axis of the tooth and also to the palatal surface of the tooth, at the incisal third of the crown over the reattachment line [Table/Fig-3a,b]. The load was applied at cross-head speed of 0.5 mm/min and was increased progressively until the reattached tooth fragment separated [Table/Fig-4] [27]. The load at which the reattached fragment debonded from the remaining tooth structure was recorded. The fracture resistance of all the specimens was recorded in the same manner pattern.

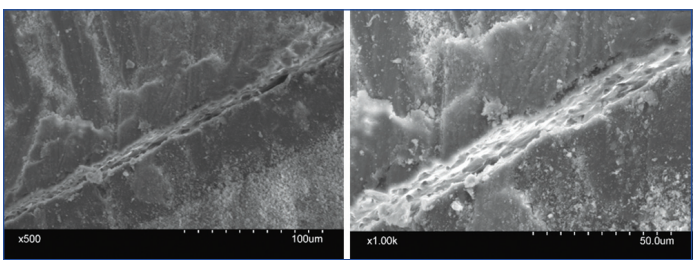
[Table/Fig-3]: a) Specimen embedded in acrylic block were mounted in UTM; b) Rod of the UTM held perpendicular to the long axis of the tooth and also to the palatal surface of the tooth, at the incisal third of the crown.

[Table/Fig-4]: Separation of reattached fragment from tooth.

- The other half of the specimen from each group was used to test bonding efficiency by measuring the distance between the reattachment material and the reattached fracture fragment. These specimens that were split into two halves longitudinally parallel to the mesial or distal sides of the tooth or perpendicular to the labial or buccal aspect of the tooth with the help of a diamond disc using slow speed to prevent breakage of the reattached fragments [Table/Fig-5]. After gold coating the specimens were put under a scanning electron microscope (HITACHI S-3400N Variable Pressure SEM) for examination [Table/Fig-6]. The specimens were examined at a magnification of 500x and 1000x [Table/Fig-7].
- The distance between the fractured segment of tooth and the reattachment material was noted down [Table/Fig-8]. All the distances measured were in µm. In the same manner the distance was calculated for each sample. The recorded data was compiled and put into statistical analysis.

[Table/Fig-5]: Reattached specimens split into two halves longitudinally.

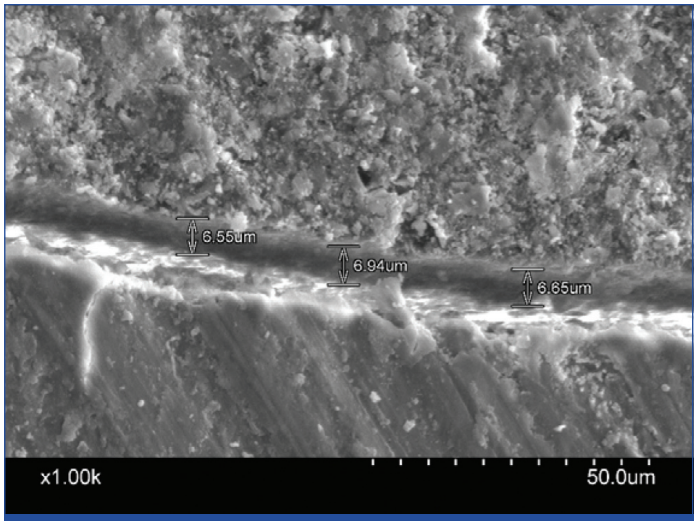
[Table/Fig-6]: SEM examination.



[Table/Fig-7]: Picture of specimen at magnification 500x and 1000x.

STATISTICAL ANALYSIS

The tabulation of the data, generation of graphs and tables were done in Microsoft Excel. The statistical analysis was done using IBM Statistical Package for Social Sciences (SPSS) statistics 27.0 (IBM Corporation, Armonk, NY, USA). Mean and Standard divisions were calculated for the continuous variables. One-way ANOVA and Tuckey's post-hoc tests were used for intergroup and intragroup comparisons. The level of significance was fixed at p=0.05 and any value less than or equal to 0.05 was considered to be statistically significant.



[Table/Fig-8]: Distance between the fractured segment of tooth and the reattachment material was noted down.

RESULTS

The total sample size was 24 for each storage media group which was again divided into half for examination into SEM and UTM. So, sample per hydration media for SEM and UTM was 12.

The study revealed that fracture resistance is the highest in **packable composite** in the **fat-free media** with a mean value of 278.09 (SD 9.54) as compared to group B and D [Table/Fig-9].

Groups	N	Mean fracture resistance	Minimum	Maximum	SD
Positive control (Group-A)	12	558.96	549.84	568.36	9.08
Normal saline (Group-B) (N=12)					
B1- Light cure GIC	4	125.35	114.25	131.65	7.77
B2 - Packable composite	4	265.25	258.36	273.76	6.37
B3 - Flowable composite	4	206.27	196.34	214.22	7.88
Fat - Free milk (Group-C) (N=12)					
C1- Light cure GIC	4	132.97	129.56	137.84	3.63
C2 - Packable composite	4	278.09	266.38	289.1	9.54
C3 - Flowable composite	4	223.42	214.26	230.71	7.08
Not stored in any media (Group-D) (N=12)					
D1- Light cure GIC	4	73.67	69.41	78.87	4.46
D2 - Packable composite	4	164.59	158.11	173.14	6.49
D3 - Flowable composite	4	153.62	148.32	161.27	5.64

[Table/Fig-9]: Mean fracture resistance of reattached teeth (in Newton N) using 3 different materials in fractures teeth soaked in three different media.

The highest fracture resistance is seen in the **Fat-free milk media** among the hydration media with a mean value of 132.97 for reattachment with light cure GIC, 278.09 for reattachment with packable composite and 223.42 for reattachment with flowable composite.

Distance between restoration and tooth surface is the smallest in **packable composite** in the **fat-free media** with a mean value of 1.4131 µm (SD 0.12880) [Table/Fig-10].

The smallest distance between restoration and tooth surface is seen in the **fat-free milk media** among the hydration media.

Groups	N	Mean Distance between restoration and tooth surface	Minimum	Maximum	SD
Normal saline (Group-B) (N=12)					
B1- Light cure GIC	4	4.4166	2.74	5.49	1.09451
B2 - Packable composite	4	2.1512	1.51	3.69	0.83857
B3 - Flowable composite	4	3.5019	2.71	4.05	0.49025
Fat- Free milk (Group-C) (N=12)					
C1- Light cure GIC	4	3.5019	2.71	4.05	0.49025
C2 - Packable composite	4	1.4131	1.23	1.56	0.12880
C3 - Flowable composite	4	2.1188	1.88	2.71	0.36531
Not stored in any media (Group-D) (N=12)					
D1- Light cure GIC	4	6.5281	6.40	6.72	0.12342
D2 - Packable composite	4	3.6903	2.74	4.71	0.57124
D3 - Flowable composite	4	4.6506	3.54	5.49	0.85803

[Table/Fig-10]: Distance between restoration and tooth surface using SEM, in 3 different materials in fractures teeth soaked in three different media.

The smallest distance between restoration and tooth surface is seen the group reattached with **packable composite** among the reattachment materials.

One-way ANOVA (analysis of variance) test shows that, there is a statistically significant difference between the three fracture repair materials for different soaking medias Gr B, Gr C and Gr D [Table/Fig-11].

Groups		Mean Square	F	Sig.
Gr A	Between groups	0.000	0.000	1.000
	Within groups	82.444		
	Total			
Gr B	Between groups	19733.864	362.495	p≤0.001**
	Within groups	54.439	240.579	
	Total		484.410	
Gr C	Between groups	28078.785	430.960	p≤0.001**
	Within groups	65.154	646.440	
	Total		215.480	
Gr D	Between groups	9852.756	314.179	p≤0.001**
	Within groups	31.360	407.674	
	Total		220.683	

[Table/Fig-11]: Inter-group and Intra-group comparison of fracture resistance of teeth using One-way ANOVA.
**Statistically significant (p<0.05)
** Between groups mean between the hydration groups
** Within groups mean between the different reattachment material group

Tuckey's Post-hoc test shows that, there is a statistically significant difference between the distance between restoration and tooth surface different soaking medias with relation to three different soaking medias - Gr B, Gr C and Gr D [Table/Fig-12].

Multiple comparisons						
Dependant variable: VAR00010						
Tukey HSD						
Groups	Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Gr B (Normal Saline)	Gr C (Fat-free milk)	1.01198*	0.34306	0.012**	.1903	1.8337
	Gr D (Dry)	-1.59979*	0.34306	p≤0.001	-2.4215	-0.7781
Gr C (Fat-free milk)	Gr B (Normal Saline)	-1.01198*	0.34306	0.012**	-1.8337	-0.1903
	Gr D (Dry)	-2.61177*	0.34306	p≤0.001	-3.4335	-1.7900
Gr D (Dry)	Gr B (Normal Saline)	1.59979*	0.34306	p≤0.001	0.7781	2.4215
	Gr C (Fat-free milk)	2.61177*	0.34306	p≤0.001	1.7900	3.4335

[Table/Fig-12]: Inter-group comparison of distance between restoration and tooth surface using Tuckey's Post-hoc test.
**Statistically significant (p<0.01)

DISCUSSION

Liew VP perhaps best described reattachment procedure as an excellent short to medium term temporary restoration with potential for indefinite service [28]. Andreasen FM et al., in a multi-centre clinical trial demonstrated a 25% retention rate of reattached coronal fragments at seven years [3]. Cavalleri G and Zerman N in another study showed a 43% success at five years [29].

Advancement in the adhesive dentistry, restorative materials, preparation designs and the use of fibre post have enabled restorative dentists to restore fractured teeth predictably and also has led to an improvement in success and longevity of tooth reattachment. Survival rate of this method of restoration has been reported to be good while further studies have been recommended [30-32].

The predicted eventual separation of the repair because of progressive breakdown of the bonded junction (cyclic fatigue, hydrolytic degradation) is one of the disadvantages of reattachment. The debonding in many cases are caused by non-physiological use of the restored teeth or new traumas. The modest longevity of such restorations justifies a search for ways to improve the durability of the bond established by the fragment-bonding technique.

The important requirements of reattachment procedure include precise adaptation and a good material to join the two parts [33,34]. An ideal dental material used for reattachment procedure must possess good mechanical properties to overcome the stress during mastication along with good biocompatibility, good bond strength and minimal gingival irritation.

The differences in the bond strengths between previous literature and the present study may be due to the different chemical compositions and curing procedures of bonding agents used [35]. It should also be considered that another reason for this difference may be due to the biochemical and histological differences between dental tissues of human and animal teeth which was used for experimentation in past literature [35].

The results of this study demonstrated that fragments stored in fat-free milk had the highest fracture resistance followed by the group stored in normal saline, placing the group that was stored dry with the least fracture resistance which is in accordance to a study by Farik B et al., who reported that the strength of the bond between the tooth fragment and tooth remnant is reduced when the fragment is kept in a dry environment for more than one hour prior to its reattachment [36].

In the present study the teeth reattached with flowable composite showed fracture resistance lower than teeth reattached with flowable composite resin (Prevest DenPro Fusion Flo). It could be attributed to the lower filler content of flowable composite (20-25% lesser filler loading) as compared to composite resin. Lower the filler content, inferior is the bond strength of the resin.

When the fractured segment is available, tooth fragment reattachment is, therefore, a valid and viable treatment option for management of coronal tooth fracture especially in the anterior region. It is also recommended a standardised long term period study be conducted in future; to further evaluate the survival rate of this treatment approach.

Limitation(s)

However long-term clinical trials as well as in vitro studies on larger number of samples and at larger scale need to be undertaken,

before drawing any definitive conclusion. One of the disadvantages of reattachment is the predicted eventual separation of the repair because of progressive breakdown of the bonded junction (cyclic fatigue, hydrolytic degradation)

CONCLUSION(S)

Within the limits of the present investigation, it can be concluded from the present study that Fracture resistance of reattached teeth in different groups varied for an intact tooth. Reattachment with packable composite resin provides the highest fracture resistance. Whereas Reattachment with light curing glass ionomer cement was the weakest. Fracture resistance after fragment reattachment was significantly affected by hydration media. Fracture resistance of fragments rehydrated fat-free cold milk was better than that of fragments rehydrated by immersion in normal saline or stored dry. Fracture resistance of fragments that were stored dry was the least.

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