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Original Research

Comparative evaluation of fracture resistance and type of failure in three restorative alternatives used for the reattachment of a fractured maxillary central incisor: An in vitro study

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A R T I C L E I N F O

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A B S T R A C T

Coronal fractures of the anterior teeth are the most common form of dental trauma that mainly affects the maxillary incisors because of their position in the arch. It has been a common challenge for dental professionals because many different protocols for treatment are currently available. Reattachment of tooth fragments is one of the most conservative options for managing coronal tooth fractures, especially when the fractured fragment is intact with adequate and correctly preserved margins. The study aimed to evaluate and compare the fracture resistance and detect the type of failure among the Paracore, Resin cement, and Flowable composite used to reattach the fractured tooth fragment in anterior teeth.

Introduction

Traumatic dental injury refers to physical injuries of sudden onset and severity that cause damage to the teeth and their supporting structures and requires immediate attention.[1] Among all these injuries; uncomplicated traumatic dental is the most frequent type of traumatic dental injury in children and adolescents, as they account for approximately two-thirds of all diagnosed traumatic dental injuries.[2]

It is documented that more than 20% of children experience damage to their permanent dentition by 14 years of age, and the peak incidence at the 8-10 years of age. [3] Coronal fracture of permanent incisors represents 18% – 22% of all trauma to dental hard tissues; of these 96% involves maxillary incisors (central incisors 80%, and lateral incisors 16%).[4] Teenagers and children are most commonly affected because of their involvement in contact sports, automobile accidents, outdoor activities, and falls.[5]

Traumatic dental injuries involving the anterior teeth not only lead to compromised tooth functioning, speech, and facial aesthetics; but also have a psychological impact on the child and his parents as well.[4] These injuries not only cause pain and discomfort but can affect the most endearing quality of a human being which is their smile.[6]

A variety of treatment modalities have been tried for managing crown fractures including composite resins with acid-etch adhesive, porcelain veneers, and jacket crowns. But none of the above-mentioned techniques can efficiently

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reproduce the aesthetics and functions of a natural tooth without jeopardizing the tooth structure.[7]

Chosack and Eildeman described for the first time in 1964, the reattachment of tooth fragments after the trauma of a 12 years old child.[8] In contrast to the other techniques, fragment reattachment offers several advantages as it preserves the original shape, color, brightness, and surface texture of enamel. Unlike other restorative modalities, incisal edges of reattached fragments tend to wear at a much similar rate compared to adjacent natural teeth. It also provides psychological comfort to the patient. Furthermore, this technique can be less time-consuming and provides more predictable long-term results.[9] When the fractured portion is intact, with adequate and correctly preserved margins, the adhesive reattachment to the residual tooth structure represents the first choice of treatment.[10]

The prognosis of the treatment depends on the type of adhesive material used for reattachment and its ability to resist fracture under load. The reattached fragments are prone to re-fracture if another traumatic episode occurs or under non-physiological use of the restored teeth. Therefore a strong, durable and predictable union between the fractured fragment and the remaining tooth is the prime determinant.[11]

Most concerns about reattachment techniques have been directed towards the fractural strength of the restored tooth. There are many adhesive materials now available in the market but the choice of material with higher impact strength and which can retain the reattached fractured tooth fragment for a longer time is still tough to decide.[12]

Material and Methods:

A total of 40 sound freshly extracted human permanent maxillary incisors were collected. Out of these, 10 teeth were maintained as a control group. The Remaining 30 teeth were divided equally and randomly into 3 groups (n=10) based upon the materials used for reattachment of fractured tooth fragments.

Grouping of samples:

GROUP 1 : (n=10) Control group in which intact teeth were taken

GROUP 2 : (n=10) Paracore was used for the reattachment of fractured tooth fragments

GROUP 3 : (n=10) Resin cement was used for the reattachment of fractured tooth fragments.

GROUP 4: (n=10)Flowable composite was used for reattachment of fractured tooth fragments

Sample preparation

In the other three experimental groups, the teeth were marked 2.5 mm below the incisal edge with the help of William's probe and a black marker. Small notches were placed on the two proximal surfaces of all teeth in the experimental group with a diamond wheel 2.5 mm from the incisal edge. A narrow forcep (4mm wide) was used to fracture the teeth at the notches parallel with the incisal edge.

The incisal fragments were held by a piece of sticky wax and the two surfaces were reattached by using respective adhesive materials as recommended by the manufacturer. Test samples will be mounted in acrylic blocks up to cement-enamel-junction using auto-polymerized acrylic resin with a long axis perpendicular to the base of the block. The fracture resistance of each specimen was measured using the universal testing machine. In all specimens, a knife-edge chisel (0.5 mm in cross-section) was used to deliver the forces so that contact was achieved 2mm from the incisal edge. The shearing load was applied at a cross head speed of 1mm/min and increased progressively until the reattached tooth fragment separated. The shearing force at which reattached fragments were fractured from the remaining tooth structure was noted and shear bond strength was calculated and recorded.

After the evaluation of fracture resistance, the specimens were examined under Scanning Electron Microscope to evaluate the site where the failure occurred.

Data were analyzed by ANOVA, Post Hoc test (Bonferroni procedure), and multiple comparisons.

RESULTS AND OBSERVATIONS

The result in the present study are tabulated as follows:

Table 1: shows the mean fracture resistance in different study groups.

Maximum fracture resistance was seen associated with intact tooth followed by Paracore, Solocem and least in Brilliant flow.

Table 2: Analysis of Variance of Fracture Resistance

Since the data was normally distributed analysis of variance test (ANOVA) was applied to compare the fracture resistance of intact teeth and the three experimental groups. Comparison of fracture resistance among the study groups (Table 2) showed that there was a statistically significant difference in mean fracture resistance ($P<0.001$).

Table 3. Multiple comparisons

For intergroup comparison, the Post Hoc test was used.

Multiple comparisons (Table 3) showed the following findings:

- There was a statistically significant difference in mean fracture resistance between the intact tooth and the Paracore ($P<0.001$).
- There was a statistically significant difference in mean fracture resistance between the intact tooth and Solocem ($P<0.001$).
- There was a statistically significant difference in mean fracture resistance between the intact tooth and Brilliant flow ($P<0.001$).
- There was a statistically significant difference in mean fracture resistance between Paracore and Solocem ($P<0.001$).
- There was a statistically significant difference in mean fracture resistance between Paracore and Brilliant Flow ($P<0.001$).
- There was a statistically significant difference in mean fracture resistance between Paracore and Solocem ($P<0.001$).
- There was a statistically significant difference in mean fracture resistance between Paracore and Brilliant Flow ($P<0.001$).

SEM IMAGES:

Specimens were examined under Scanning Electron Microscope to evaluate the site where the failure occurred.

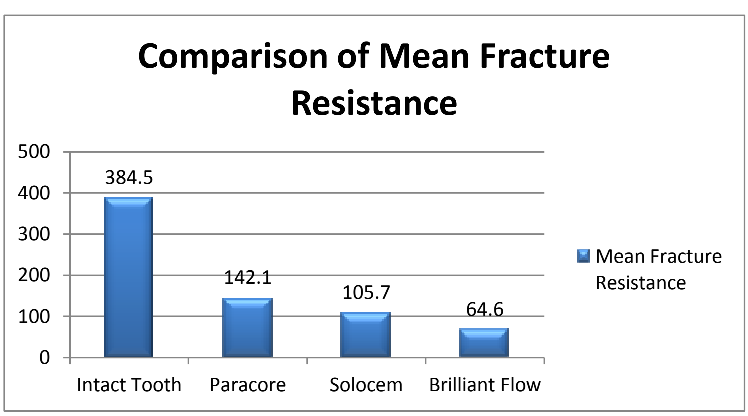
IMAGE 1a: SEM micrograph of a cohesive resin fracture with Paracore-Coltene).

IMAGE 1b: SEM micrograph of an adhesive resin fracture

Table 1: shows the mean fracture resistance in different study groups.

	N	Mean	Std. Deviation	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Intact tooth	10	384.5450	19.77378	370.3997	398.6903	355.64	410.54
Paracore	10	142.1350	7.29249	136.9183	147.3517	132.40	152.32
Solocem	10	105.6910	9.78446	98.6916	112.6904	90.89	120.45
Brilliant Flow	10	64.6470	10.40362	57.2047	72.0893	48.90	78.73
Total	40	174.2545	126.64492	133.7515	214.7575	48.90	410.54

Graph 1: Graph shows the bar graph of mean fracture resistance of different groups



	Sum of Squares	df	Mean Square	F	P-value
Between Groups	619685.143	3	206561.714	1274.770	<.001*
Within Groups	5833.382	36	162.038		
Total	625518.524	39			

Table 2: Analysis of Variance of Fracture Resistance

(I) Group	(J) Group	Mean Difference (I-J)	P-value	95% Confidence Interval	
				Lower Bound	Upper Bound
Intact tooth	Paracore	242.41000*	<.001*	227.0781	257.7419
Intact tooth	Solocem	278.85400*	<.001*	263.5221	294.1859
Intact tooth	Brilliant Flow	319.89800*	<.001*	304.5661	335.2299
Paracore	Solocem	36.44400*	<.001*	21.1121	51.7759
Paracore	Brilliant Flow	77.48800*	<.001*	62.1561	92.8199
Solocem	Brilliant Flow	41.04400*	<.001*	25.7121	56.3759

Table 3: Multiple comparisons

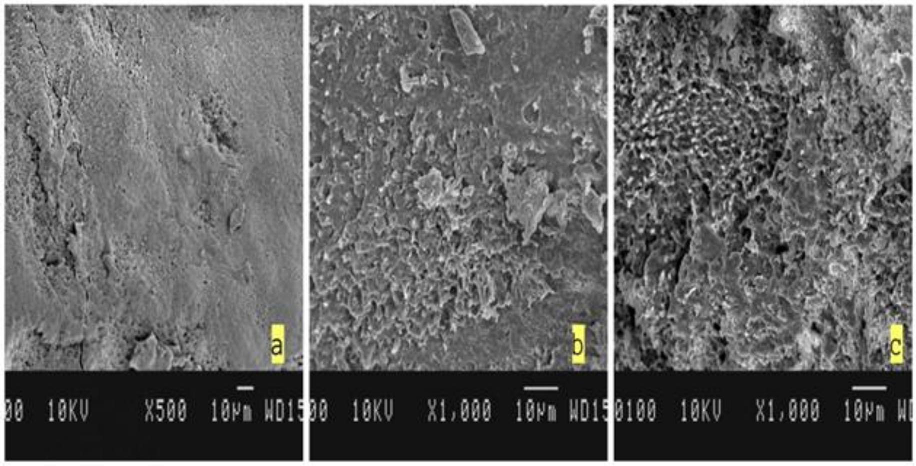


FIGURE 1: a) SEM micrograph of a cohesive resin fracture with Paracore-Coltene. b) SEM micrograph of a adhesive resin fracture with Solocem- Coltene. c) SEM micrograph of a mixed resin fracture with brilliant flow- coltene.

with Solocem- Coltene.

IMAGE 1c: SEM micrograph of a mixed resin fracture with the brilliant flow- Coltene.

Discussion

The in vitro study was undertaken to study fracture resistance and type of failure which would act as screening tools to understand and predict the clinical behavior of Paracore, Resin Cement, and Flowable composite used for reattachment of the fractured fragment.

The results of the present study were in the following order:

Group 1(intact teeth)>Group 2(paracore)>group 3(solocem)>Group 4 (brilliant flow)

Post hoc test showed a statistically significant difference between mean fracture resistance of intact teeth and experimental groups ($p<0.001$)

Among the experimental groups, teeth reattached with paracore showed the highest resistance to fracture. This could be attributed to its excellent mechanical properties. This could be due to the presence of glass particles and macroscopic size of the unidirectional fiber bundles The presence of these fibers affects the fracture process by interrupting crack growth progression which in turn enhances the fracture toughness of the material.[13]

The second possible explanation of better physical properties could be the presence of a dual-cure polymerization stage in this cement which causes more composite conversion. On the other hand, resin hardening results in a longer pre-gel stage in composite polymerization, and during this stage, the material becomes elastic, absorbs and distributes stresses. The longer the period of the pre gel stage there will be lesser stress and the resultant bond strength will be more.[14]

In addition, its fracture resistance is high due to the difference in its bonding mechanism to enamel and dentin in comparison to other groups. It is based on the total-etch technique. The two-stage adhesives were more effective in cementation which may be attributed to their enhanced bonding.[15] This is supported by the evidence where total-etch systems appear to be more favorable than self-etch and the lower mean bond strengths are associated with the self-etch.**[16]**

SEM investigation showed that cohesive failure was the major fracture mode for paracore (resin internal destruction) and that there were more resin tags in the dentin than for the other groups. Because paracore is a two-step adhesive, with demineralization depths relatively consistent with the depth of resin tags, it had the minimal micro-groove between demineralization depth and resin infiltration depth which means that the bond strength at the dentin-resin interface may have been higher.[17]

The teeth reattached with solocem showed fracture resistance lower than teeth reattached with paracore. It could be attributed to its different bonding mechanisms to enamel and dentin. Despite the initial acidic pH due to the presence of 4-META, self-adhesive resin cement did not produce any evidence of dentin demineralization or hybridization at the micro-meter level**.[18]** The decreased bond strength of the self-adhesive resin cement may be attributed to the limited penetration and superficial demineralizing action.[19]

In addition, the monomeric composition of self-adhesive cement also differs from conventional ones. They are composed of acid-functional adhesive resinous monomers which are a type of monomeric methacrylate that has a phosphoric acid or carboxylic acid grouping in their molecular structure. The presence of functional monomers may be hindering the functioning of the amine initiator and compromising its mechanical properties.[20]

It showed fracture resistance higher than teeth reattached with the brilliant flow. This could be due to its superior physical and polymerization properties. It shows low polymerization shrinkage compared to flowable composites due to its dual-cure nature. This, in turn, causes the unpolymerized resin to polymerize which contributes to its high mechanical properties.[21] self-adhesive cement has excellent mechanical properties in terms of flexural strength, elastic modulus, and water absorption, which they attribute to the presence of 10-methacryloyloydecyldihydrogen phosphate (MDP) in them.[22]

SEM showed that adhesive failure was the major fracture mode for SoloCem and occurred in the interface of resin and dentin, with few resin tags in the dentin. Its inability to completely remove the smear layer may account for the decreased bond strength as it has been proven that to achieve a favorable bond to dentin, the smear layer must be removed and collagen fibers exposed to let the adhesive materials enter this network.[23]

Teeth reattached with brilliant flow showed the least resistance to fracture. This could be due to their inferior physical properties because of limited filler loading which is 37%-53% per volume, typically display lower physical properties.[24] Flowable composites typically exhibit higher polymerization shrinkage than Paracore and Solocem because they need penetration of light for polymerization. Because the light intensity decreases while penetrating through the tooth tissues, polymerization is insufficient, thus the physical and mechanical properties decrease.[14]

SEM showed that mixed failure was the major fracture mode for brilliant flow and occurred both within the resin itself and within the resin-dentin interface. High curing shrinkage: due to lower filler load, weaker mechanical properties, low edge strength were some of the reasons for mixed failure.

Conclusion

Within the limitations of the study, it can be concluded that the different materials used for reattachment of the fractured fragment were not able to attain the fracture resistance as that of intact teeth in the control group. Among the experimental groups, Paracore provided the highest resistance to fracture followed by Solocem and Brilliant flow. SEM evaluation showed cohesive failure as the principal fracture mode for Paracore, adhesive failure for SoloCem, and mixed failure for Brilliant flow. Hence, proper selection of materials is of utmost importance, as it determines the strength of reattached fragment to the tooth. However, the bonding procedure also plays an important role and should be carried out carefully because flaws during the bonding procedure reduce the bond strength of the segments.

Overall, the paracore seemed appropriate for use as an intermediate material for the reattachment of fractured tooth fragments with regards to its mechanical properties and bond strength.

This in vitro study needs to be carried out under ex in-vivo conditions to analyze the best material under clinical conditions. Further studies with a large sample size are required to come to a definite conclusion.

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