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Comparative Evaluation of Fracture Resistance and Microleakage of Reattached Anterior Tooth Fragment Using Two Different Flowable Composites- An *in vitro* Study

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Authors' contributions

This work was carried out in collaboration between all authors. Author Saumya designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RD and AG managed the literature searches. Author BK discussed lab procedure and helped in that. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To evaluate and compare the fracture resistance and microleakage of reattached anterior tooth fragment using two different flowable composites.
Study Design: *In-vitro* study.
Place and Duration of Study: The present in vitro study was carried out in the Department of Pedodontics and Preventive Dentistry, Faculty of Dental Sciences, SGT University, between June 2014 and July 2016.
Methodology: The subjects were selected from various sources. A total of 160 extracted permanent anteriors were selected for the study. Teeth were divided into 2 groups, 80 teeth in each group reattached with G-aenial Universal Flo and Esthet X-Flow, evaluated for fracture

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resistance testing using Universal testing machine. Half number of teeth tested for microleakage using Dye-penetration method. The results obtained from the study were then tabulated and statistically analyzed.

Results: Mean value for fracture resistance in Group I were observed (89.07 ± 32.46) whereas in Group II were observed (64.63 ± 40.33). On statistical analysis result found to be highly significant (p = 0.001). Out of 40 teeth, in Group I -16 observed no penetration whereas in Group II -10 teeth were observed no penetration. On Enamel-Dentin microleakage in Group I found to be in 6 teeth, whereas 14 teeth showed the same Enamel-Dentin penetration in Group II. But on statistical analysis, overall result found to be non-significant (p = 0.19).

Conclusion: Among the tested flowable composites, G-aenial Universal Flo showed highly significant fracture resistance than Esthet X-flow. Microleakage shows no significant differences between nanohybrid and microhybrid flowable composites.

Keywords: Reattachment of tooth fragment; Fracture resistance; microleakage; flowable composite.

1. INTRODUCTION

Anterior crown fractures of maxillary teeth are a common form of dental injury that mainly affects children and adolescents.[1-3] The position of maxillary incisors and their eruptive pattern carries a significant risk for trauma. The incidence of dental trauma is on the rise due to involvement of children and teenagers in contact sports, automobile accidents, outdoors activities and falls.[3,4] Coronal fracture of permanent incisors represents 18-22% of all traumas to dental hard tissues; of these, 96% involve maxillary incisors (80% central incisors & 16% lateral incisors).[5-9] Traumatic dental injuries not only cause damage to the dentition, but also have a psychological impact on the child and his parents as well.[10]

Chosack and Eildeman first described reattachment of tooth fragment after trauma to 12-year-old child.[10] They suggested fixation of post in the root canal after endodontic treatment and reattached to it the coronal fragment but found this reconstruction to be only temporary The use of acid etch technique for the reattachment of fractured fragment was first reported by Tennery.[11]

The success of reattachment depends on factors such as the fracture site, size of fractured remnants, periodontal status, pulpal involvement, maturity of the root formation, amount of biological width involved in injury, occlusion, material used for reattachment, and if use of a post is required. Reattachment is a way to restore the natural shape, contour, translucency, surface texture, occlusal alignment, and color of the fragment along with a positive emotional and social response from the patient to the preservation of natural tooth structure, and it is also an economical and a conservative procedure.[10]

Restoration of a fractured crown is important both aesthetically and functionally. Various treatment modalities used to restore the fractured crown include stainless steel crowns, orthodontic bands, pin-retained resin, resin crowns, porcelain jacket crowns, and composite build-up. These, however, may require sacrifice of healthy tooth structure. In addition, composite resins have the disadvantage of poor abrasion resistance in comparison to tooth enamel, marginal staining, discoloration, and lack of marginal integrity.[12]

A smooth flowing micro-hybrid composite resin Esther X-Flow (Dentsply), has superior mechanical properties due to higher inorganic filler content. The total filler content is about 77% by weight (60% by volume). In addition, the barium alumino-fluoro-boro silicate glass filler particles range in size from 0.02 microns to 2.5 microns (with an average of 0.6-0.8 m) while the silicon dioxide particles range from 10 nm to 20 nm. This unique particle distribution pattern provides superior strength and high fracture toughness. [13] However, the particle size of these different conventional hybrid composites are so dissimilar to the structural sizes of the hydroxyapetite crystals, dental tubules, and enamel rods, that there is a potential for compromise in adhesion between the macroscopic restorative material and nanoscopic tooth structure. Nanotechnology has the potential to improve this continuity between the tooth structure and the nanosized filler particle and provide a more stable and natural interface between the mineralised hard tissues of the tooth and these advanced restorative biomaterials. One such nano-hybrid flowable composite resin system, (G-aenial Universal Flo, GC America), may possess these improved physical, mechanical, and optical properties.[14]

In this material, strontium glass fillers with the smallest particle size seen in current flowables and composites (200 nm) are homogeneously dispersed in an amorphous complex. The use of spherical nano-fillers and nano-aggregates in composite have been firmly established in composite technology.[15,16]

Previous studies have shown that following trauma or under non-physiological use of restored teeth, the reattached fragments are prone to refracture. [3,13] Therefore, a strong, durable, and predictable bond between the fractured fragment and the remaining natural tooth structure is necessary. In taking into consideration these enhanced properties of composites for reattachment the present study was conducted to test the advantages that this material (G-aenial Universal Flo) offers and to compare its efficacy as a reattachment material with another available flowable composite (ESTHET X-FLOW).

2. MATERIALS AND METHODS

2.1 Sample

A total of 160 extracted human permanent anterior teeth were selected for the study.

Teeth were excluded if any of the following criteria were present:

- grossly destroyed, unrestorable
- previous restorations.
- visible structural defects.

Tooth preparation of uncomplicated fracture according to Andreasen classification of traumatic tooth.

[ANNEXURE-I] Andreasen and Andreasen's Classification (1993)[17]

Class I	Enamel infarction(crack)
Class II	Enamel fracture (crown fracture, not complicated)
Class III	Enamel-dentin fracture (crown fracture, not complicated)
Class IV	Complicated crown fracture
Class V	Crown-root fracture, not complicated
Class VI	Complicated crown-root fracture
Class VII	Root fracture

2.2 Procedure

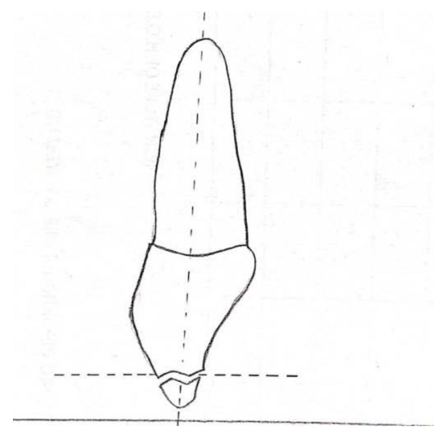
The 160 extracted teeth were divided into 2 groups, 80 teeth in each group.

- Group 1 –teeth reattached with G-aenial Universal Flo (GC America)
- Group 2 –teeth reattached with Esthet X-Flow (Dentsply)

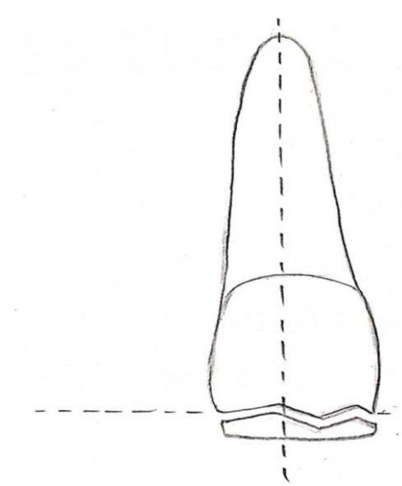
2.3 Methodology

- The extracted teeth were kept in 5% sodium hypochlorite solution for 1hour.
- Teeth collected were cleaned and stored in normal saline until use.

Tooth were sectioned transversely to the long axis of the tooth, 2.5 mm away from the incisal edge using a diamond disk. Fig. 1.



(a)



(b)

Fig. 1. Transeverse section to the long axis

- 37% phosphoric acid (Frost, Ammdent) was applied along the fractured margins of the tooth as well as the fragment for 15 seconds. The etched surfaces were then thoroughly rinsed with water and gently air-dried.
- Bonding agent (One Coat Bond SL) was applied with an applicator tip to the etched surfaces of the fractured margins of the tooth and fragment. Two consecutive coats were applied, gently air-dried and then light cured for 10 seconds.
- The material used for reattachment was then applied on a fractured surface of the tooth as well as the fragment according to manufacturer instructions. The fractured fragment was then approximated along the fractured tooth margin and light cured for 40 seconds each on the labial and lingual surfaces.
- Samples were then thermocycled between two baths, (temperature of 5-55℃) for 100 cycles with a dwelling time of 30 seconds in each bath.

2.3.1 Technique used for the evaluation of fracture resistance

Half of teeth (40) from each group were embedded in an acrylic resin block with the long axis of the tooth parallel to the central axis of the block**.** Then were then tested for fracture resistance using a universal testing machine.

The rod of the universal testing machine was held 45^0 to the long axis of the tooth at the incisal third of the crown, parallel and adjacent to the bonding line**.**

- The load was applied at cross-head speed of 1mm/min and increased progressively until the reattached tooth fragment separated. The load at which the reattached fragment were fractured from the remaining tooth structure was noted the fracture resistance recorded in kilogram's (Kg).

2.3.2 Technique for microleakage evaluation

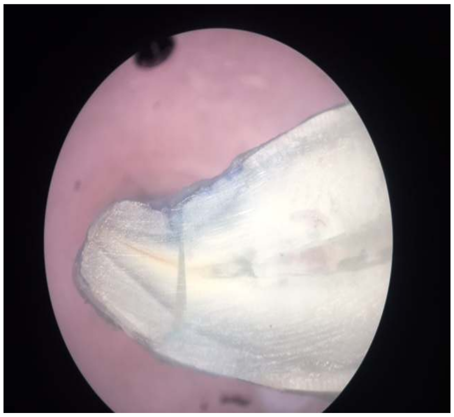
Half (40) teeth from each group were evaluated for microleakage.

- Each tooth was covered with nail varnish except an area approximately within 2 mm of periphery of the restoration.
- Teeth were immersed in 0.5% methylene blue dye solution for 24 hours at room temperature. Following removal from the dye, the teeth were cleaned rinsed with tap water and dried.
- Teeth were then sectioned mesio-distally through their long axis using diamond disc examined under a stereomicroscope at 20X magnification to measure depth of the dye penetration.
- All procedures were carried out by a single person, scoring criteria used were [ANNEXURE-II] Fig. 2.

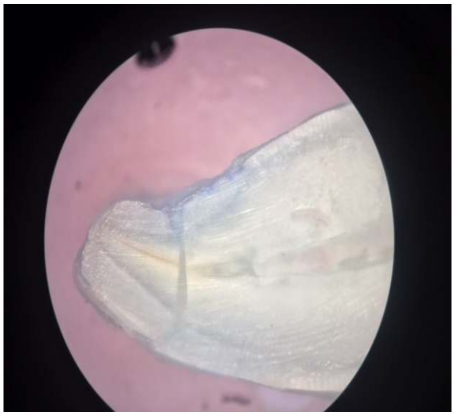
Scoring for dye penetration for marginal microleakage[18]:

Score	Criteria
0	No dye penetration
1	Dye penetration limited to enamel only.
2	Dye penetration beyond the dentino-enamel junction (DEJ)
3	Dye penetration into pulpal wall.

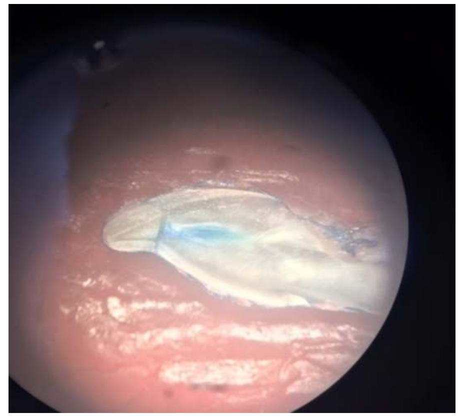
Score 0



Score 1



Score 2



Score 3

Fig. 2. Scoring criteria under 20X magnification

2.4 Analysis of the Data

The results obtained from the study were then tabulated and statistically analyzed.

3. RESULTS AND DISCUSSION

The incidences of dental trauma have increased in number among children and teenagers. Different classification systems of traumatic tooth fractures appear in the literature.[17,19] Inspite of differences in the percentage rates and classification systems used, a majority of the studies agree in several respects: 1) the most common injuries are uncomplicated crown fractures (Ellis Class I and II; Andreasen Class I, II and III, which represents enamel and enamel-dentin fractures without pulp exposure); 2) children and teenagers are most affected, with boys being the highest risk group; 3) upper central incisors are most affected and 4) traffic accidents and “at risk” atheletic activities are usually the most common cause of dental trauma. [1,20]

Reattachment of a tooth fragment is possible after‒trauma if the fragment is intact and has a good adaptation to the remaining tooth. Successful reattachment depends on the condition of the fractured remnant. Dehydration results in loss of strength; therefore, care should be taken to make sure the tooth fragment stays moist.

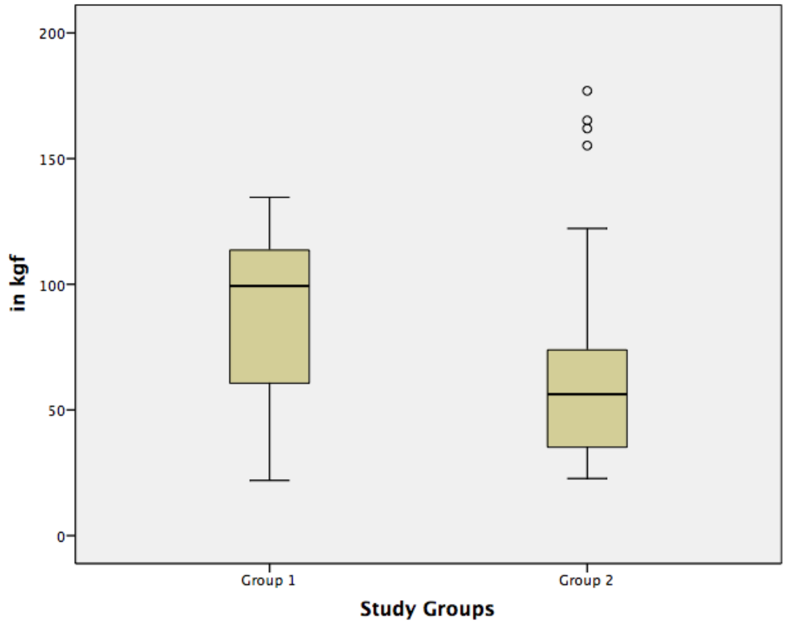
In the present study, samples were stored in saline after collection and after fragment preparation. Farik et al [21] analyzed the strength of reattached fractured teeth dehydrated for a period of 5 seconds to 24 hours. Fragments dehydrated for more than 1 hour significantly decreases in fracture resistance. However teeth reattached with fragments dehydrated for 24 hours then rehydrated in water for at least one day and night (the same period of time), didn’t lose its strength.[21] In addition. Sharmin and Thomas [22] also concluded in their study that fragments stored in saline and milk showed greater fracture resistance than those kept dried [22].

Various techniques and designs have been proposed for reattachment of fractured tooth fragments including: Bevel designs, chamfers, dentin and enamel grooves,as well as using resin composite materials.[3] The studies also differ in the way that tooth fragments are obtained. Some authors have sectioned the incisal edge of teeth.[21,23] Others have placed small notches on the two proximal surfaces and fractured the teeth by using narrow forceps or by using a blunt instrument without making any notches [17,24].

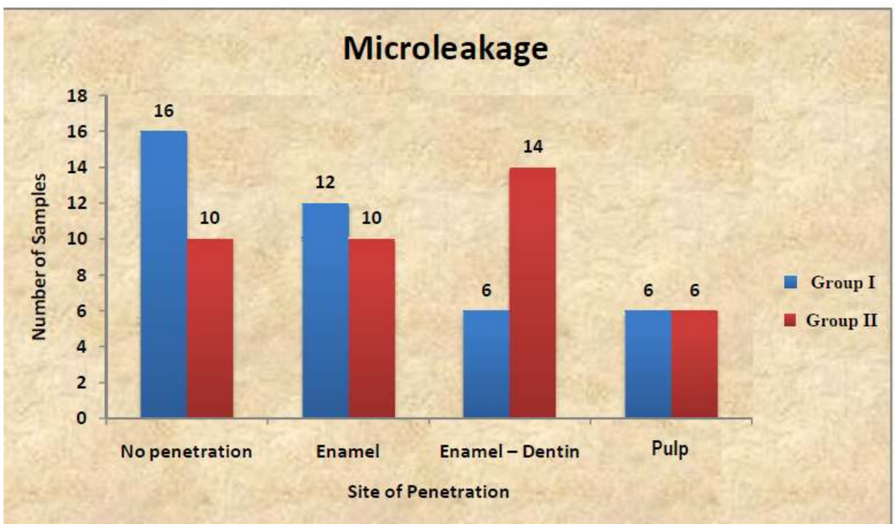
Table 1. Depicts the median value of fracture resistance of Group I & Group II

Group	Mean (SD)	Range	Median (Q1-Q3)	Mann Whitney U test	
				U statistic	p-value
I (n=80)	89.07 (32.46)	21.95 - 134.60	99.33 (60.35 - 114.05)	445.00	0.001*
II (n=80)	64.63 (40.33)	22.74 - 176.96	56.25 (35.14 - 74.21)		

**p<0.05 Statistically significant, p>0.05 Non significant, NS*



Graph 1. Comparison of fracture resistance (in kgf) between the study groups using Mann Whitney U test



Graph 2. Comparison of microleakage between the study groups

Among the tested flowable composites, G-aenial Universal Flo showed more highly significant fracture resistance (p = 0.001) when compared to Esthet X-flow.

Enamel-dentin microleakage was greater in Group II (Esthet X-flow). However, there was no statistically significant difference between the two groups tested

In this study, the teeth were cut in a standardized manner using a low-speed diamond disk. The fitting between the fragment and the tooth was not always perfect. Fracturing a tooth in vitro for research purposes has the disadvantage that the fractured fragments produced may have uneven dimensions. As a result, the amount of material required for reattachment can vary and give inconclusive results. Hence, with this limitation to simulate the natural fracture forces, the procedure of sectioning using a diamond disk was used because it allows for the standardization of the fragment size.[22] In our study, in order to obtain an equal amount of area exposed, all of the teeth were cut at the same distance from the incisor margin (2.5 mm).

Using the same method, Badami et al [12] tried to reduce to a minimum the variation of resistance to fracture due to the difference in thickness of the enamel and dentin layers present. However, the anatomy of the surface produced by the cut is certainly different from the surface resulting from the fracture. With the cut, a smear layer is produced that is otherwise not found on a fractured surface. [12] Our choice was dictated by the fact that the cut establishes a repeatable condition absolutely necessary for an *in vitro* study, although it does not exactly simulate an accidental fracture.

Sengun et al. [26], Badami et al. [12] and Worthington et al. [25] all used the same cut to study fragment bonding. The micro mechanical interlocking between the fragments and the respective remnant is is considered to be very important to provide strength for fracture strength recovery of the technique employed.

On the other hand, Reis et al. [27] concluded that the fit between fragment and the remaining teeth is lost by sectioning and the strength of reattached teeth relies solely on the bonding of the material to the sectioned interfaces and the mechanical properties of the materials used.

The choice of materials varies among case reports. The development of more effective adhesive systems has encouraged clinicians to use these newer materials to reattach fragments after trauma.[12,17,24] Otherwise, other clinicians prefer to associate adhesive systems with other materials such as flowable composites [21,23] and dual or chemically cured resin cements and its light cured version. The use of viscous materials has been suggested where adhesive systems are used, along with hybrid and micro-filled light-cured resin composites as well as chemically cured resin composites. As noted, many combinations of materials are reported in the literature but only a few studies have evaluated their performance in terms of reattaching fragments of fractured teerth. The results of our study demonstrated that the different materials were not able to attain the fracture resistance of intact teeth, which is in accordance with previous findings in the literature [12,15,25].

Materials used for reattachment of fractured teeth have been actively studied because they also influence the strength of the bond connection between the fractured tooth segment and remaining tooth structure. Andreasen et al [17] pointed out that material with comparatively high mechanical properties such as composite resin should be used in combination with adhesives to withstand functional loading.[17] In the present study, a combination of flowable composite with a seventh generation acid etch dentin bonding system were used.

Andreasen et al [28] published a multicentered clinical study investigating strength of reattached tooth fragments. Data came from three dental clinics two of which used only acid etching for fragment reattachment while the third added a bonding agent plus acid etching. The results show that the retention level is highest for fragments reattached with acid etching and bonding agent [28].

A contemporary study by Farik et al (2002) confirmed that most fifth generation bonding systems increase fracture resistance of reattached crown fragments when used in combination with resin [29].

Table 2. Comparison of microleakage between the study groups using Chi square test

Microleakage score	**Group**		**Total**
	I	**II**	
No penetration	16(40.0%)	10(25.0%)	26(32.5%)
Enamel	12(30.0%)	10(25.0%)	22(27.5%)
Enamel – Dentin	6(15.0%)	14(35.0%)	20(25.0%)
Pulp	6(15.0%)	6(15.0%)	12(15.0%)
Total	40	40	80
Chi square value (3) = 4.77, p value = 0.19(NS)			

**p<0.05 Statistically significant, p>0.05 Non significant, NS*

In our experimental groups, G-aenial Universal Flo is nanohybrid flowable composite (G-aenial Universal Flo Technical Manual) whereas Esthet X is a micro-hybrid composite. [30] The presence of nanofiller particles in resin based restorative materials produces superior performance compared to microparticles. [31] This was also shown in our study as Esthet X-flow was found to be the weaker of the materials tested.

Composite resins containing a high percentage of UDMA have greater viscosity and increased shear bond strength. [32] Incorporation of nano-sized strontium glass as filler particles reinforces the strength of the material. [33] This could be a possible cause for G-aenial Universal Flo being better than Esthet X-flow.

Singhal and Pathak [13] performed an *in vitro* study where they concluded that composite resin provided the highest fracture resistance for fragment reattachment when compared with resin-modified glass ionomer cement, compomer and dual cure resin cement [13].

Different methodologies have been employed in laboratory articles. For instance, among several sources of variation found in these methodologies, it has been demonstrated that the crosshead speed might alter the results obtained. The mean fracture strength of fragment-bonded teeth decreases with increasing cross-head speed. [17] Prior *in vitro* studies of incisal edge reattachment have employed crosshead speeds ranging from 0.5 mm/min to 1.0 mm/min [12,24].

In the present study we used crosshead speed of 1 mm/min. Andreasen et al. [17] investigated the effect of loading fragments bonded with Scotchbond Multi-Purpose at 1,5,50,100 and 500 mm/min and noted that fracture strength decreased exponentially with loading speed [17].

Polymerization shrinkage of dental resin composites occurs because monomer molecules are converted into a polymer network and, therefore, exchange van der Waals spaces into covalent bond spaces. This polymerization shrinkage creates contraction stresses in the resin composite restoration leading to microleakage and internal stress in the surrounding tooth structure. [34] Reduction of the polymerization shrinkage may be an important issue in the use of dental resin composites. [35] Thus, in spite of much advancement with composite restoratives and bonding agents, reliable adhesion without marginal gap formation has proven elusive.

Our present study revealed a similarity in enamel microleakage between both the agents tested. Enamel-dentin microleakage in Group I found in 6 teeth; whereas, 14 teeth in Group II demonstrated enamel-dentin penetration. However, overall, there was no statistically significant difference in marginal microleakage between the two groups. Similarily, Scotti et al. [36] concluded that nanohybrid resin composites and bulk fill flowable resins showed similar microleakage values at enamel margins [36].

4. CONCLUSION

Within the limits of the present investigation, the following can be concluded from our study:

- Between the tested flowable composites, G-aenial Universal Flo showed more highly significant fracture resistance ($p = 0.001$)when compared to Esthet X-flow.
- Enamel-dentin microleakage occurred more frequently in Group II teeth treated with Esthet X-flow.
- There is no significant difference in microleakage between nanohybrid and microhybrid flowable composites.

When using G-aenial Universal Flo with an appropriate technique, esthetic results can be achieved with a predictable outcome. This provides dental clinicians with another approach to treating fractured anterior teeth and provide better esthetic and functional restorations on traumatized teeth in adults as well as in younger patients.

CONSENT

It is not applicable.

ETHICAL APPROVAL

"All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki."

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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