Dental Traumatology 2011; 27: 225–229; doi: 10.1111/j.1600-9657.2011.00990.x

Fracture resistance of microhybrid composite, nano composite and fibre-reinforced composite used for incisal edge restoration

Chandrashekhar M. Badakar[1], Kukkalli Kamalaksharappa Shashibhushan[2], N. Sathyajith Naik [2], Vulavala Venkata Subba Reddy[2]

[1]Department of Pedodontics and Preventive Dentistry, Rural Dental College, Loni, Maharashtra; [2]Department of Pedodontics and Preventive Dentistry, College of Dental Sciences, Davangere, Karnataka, India

Correspondence to: Chandrashekhar M. Badakar, Department of Pedodontics and Preventive Dentistry, Rural Dental College, Loni, Maharashtra, India
Tel.: +917709945907
Fax: +91-2422-273413
e-mail: badakar@gmail.com

Accepted 2 January, 2011

Abstract – Traumatized anterior teeth need quick, aesthetic and functional repair. Along with aesthetics, the physical properties of restorative material should also be considered for long-lasting restoration. Fibre reinforcement has been tried as a newer technique to improve the physical properties of composite materials. Hence, this study was carried out to evaluate the fracture resistance of microhybrid composite, nano composite and fibre-reinforced composite used for restoration of incisal edge of fractured maxillary central incisors. Extracted permanent maxillary central incisors were randomly divided into four groups of 10 samples each: control group with intact teeth (Group A), microhybrid composite (Esthet X; Dentsply/Caulk, Milford, DE, USA) (group B), nano composite (Ceram X; Dentsply/Caulk) (group C) and microhybrid composite reinforced with polyethylene fibre – flowable composite unit [(Ribbond THM; Ribbond Inc., Seattle, WA, USA; Esthet X flow; Dentsply/Caulk)] (group D). The fracture resistance was measured under universal testing machine at a speed of 1 mm min^{-1} with the loading tip of 2 mm diameter. The samples were further evaluated for mode of fracture under stereomicroscope at 3.5× magnification. The data were analysed using one-way ANOVA and Tukey's test for fracture resistance. Group A and group D exhibited significantly higher fracture resistance than group B and group C. No significant difference was found between group B and group C as well as between group A and group D. Fisher's exact test for the mode of fracture revealed no statistical significance. It was concluded that fibre reinforcement of composite could be an alternative technique for restoration of fractured anterior teeth for better aesthetics and longevity of the restoration.

Anterior crown fractures are a common form of injury that mainly affects children and adolescents (1). The incidence of dental trauma is on the rise owing to various factors that involve children. Based on available evidence, these aetiological, predisposing and risk factors can be broadly classified into anatomic and socio-behavioural factors. The anatomic factors contributing for increase risk of anterior teeth injuries are the substantial maxillary incisor overjet and inadequate lip coverage whereas the socio-behavioural factors include gender (males > females), adverse psychosocial environment, problem behaviour, increased participation in sports, recreational activities and low socio-economic status (2, 3).

It is estimated that nearly 15–25% of population under the age 18 years would have suffered some injury to the upper and lower incisors (3, 4). The most common injuries (51%) among these are the uncomplicated crown fractures, which represent enamel, and enamel–dentine fractures without pulp exposure (1, 5). As the dominant element of the dento-labial composition, maxillary central incisors are the teeth most visible during normal functioning (6). Trauma to the anterior teeth with the underlying aesthetic, psychosocial, functional and therapeutic problems adversely affects an individual's quality of life (7). Hence, the immediate treatment of such a condition is required.

A number of techniques have been developed to restore fractured crowns. Early techniques include orthodontic bands, pin-retained resins, basket crowns and composite resins with acid etch adhesive technique, porcelain veneers, jacket crowns and most recently being the reattachment of the fractured fragment (8). Fracture resistance of a material is a measure of its ability to retard crack initiation and propagation (4). High fracture resistance of the restorative material is required in the clinical situations where the high impact stresses are experienced and incisal angle restoration is one such demand. However, the reattachment of the fractured fragments is an aesthetically acceptable technique, but the problem of such restoration is their tendency to re-fracture or debond, most often owing to new trauma (7). Attempts have been made to improve the fracture resistance of restoration by using different bonding agents, adhesive resins and different restorative techniques. However, by using these techniques, a fracture resistance of 50–60% was obtained when compared to intact enamel.

Different fibre types have been added to composite material to improve their physical and mechanical properties, which include glass fibres, carbon fibres, Vectran fibres and Kevlar fibres. Polyethylene fibres improve the impact strength, modulus of elasticity and flexural strength of composite material. Unlike carbon and Kevlar fibres, polyethylene fibres are almost invisible in the resinous matrix and for these reasons seem to be the most appropriate and aesthetic strengthener of composite material (9, 10).

This study was carried out to compare the fracture resistance of microhybrid composite, nano composite and fibre-reinforced composite (FRC), used for restoration of fractured incisal edge, and to evaluate the mode of fracture of the restoration.

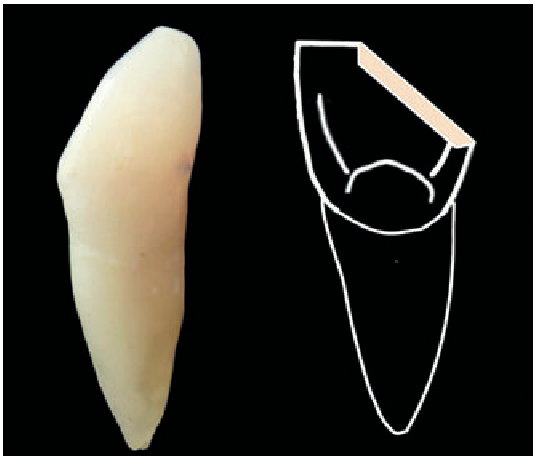

Fig. 1. Obliquely cut incisal edge.

Methodology

Human non-carious permanent maxillary central incisors extracted for periodontal problems were collected. The ethical clearance for the use of extracted tooth was obtained from the institution ethical committee. All teeth were thoroughly cleaned free of debris and calculus using scalers and stored in 1% chloramine solution. Teeth showing any visible cracks were excluded from the study. Selected teeth were randomly divided into four groups of 10 teeth each; control group (Group A), microhybrid composite group (Group B), nano composite group (Group C) and microhybrid composite reinforced with polyethylene fibre – flowable composite unit [(Ribbond THM; Ribbond Inc.; Esthet X flow; Dentsply/Caulk)] (group D).

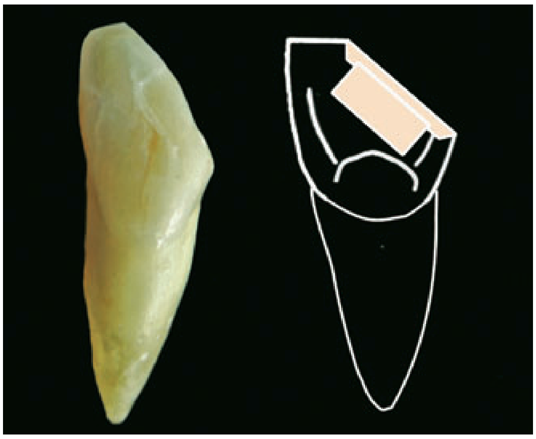

Fig. 2. A palatal cavity within the thickness of enamel, 0.5 mm depth and 5 mm width, was prepared approximately at the centre of fracture line.

Sample preparation

The samples in the group A were unprepared and used as control. In the other three experimental groups, the incisal edge was cut obliquely, extending incisally from the mesial or distal surface with a diamond disc mounted on a slow speed micromotor hand piece (Ultimate 500K; NSK, Kanuma, Japan) directed perpendicular to the labial surface of teeth (Fig. 1). Teeth showing any visible pulp exposures and cracks were excluded from the study.

Sample restoration

The prepared tooth surface was etched with 37% phosphoric acid gel (Etch 37; Bisco Inc., IL, USA) for 15 s. Subsequently, the gel was rinsed thoroughly and the tooth structure gently air-dried. Dentin primer and adhesive were applied according to the manufacturer's instructions and polymerized using LED light-curing unit (Elipar Freelight 2; 3M Espe, Seefeld, Germany) for 20 s. The lost tooth structure was freehand built with microhybrid composite (Esthet X; Dentsply/Caulk) and nano composite (Ceram X; Dentsply/Caulk) for group B and group C, respectively, and polymerized, incrementally, to recreate the missing incisal portion of the teeth using the LED light-curing unit as per the manufacturer's instructions for 40 s from both the labial and lingual aspects of the teeth.

For group D, a palatal cavity of 0.5 mm depth and 5 mm width was prepared within the enamel (Fig. 2) with fine diamond bur using a water coolant. Same etching and adhesive bonding systems were used as in group B and C. Flowable composite (Esthet X flow; Dentsply/Caulk) was placed in the palatal cavity. Before curing it, a required size of polyethylene fibre (Ribbond THM; Ribbond Inc.) was placed in the cavity as close to enamel as possible, carrying it above the fractured edge (Fig. 3). The fibre was entirely covered with a thin layer of flowable composite and then light cured for 20 s as per the manufacturer's instructions. The remaining portion of the lost tooth structure was freehand built with microhybrid composite (Esthet X; Dentsply/Caulk) and polymerized, incrementally (Fig. 4).

All the samples were mounted into an acrylic block (diameter 3 cm) at the cemento-enamel junction using auto-polymerized acrylic resin (DPI, Dental products of

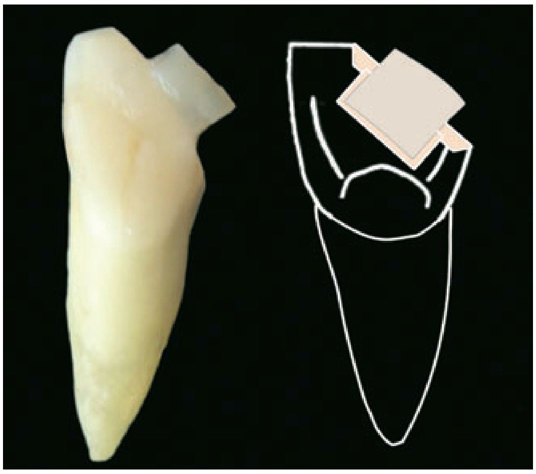

Fig. 3. After etching and bonding, the flowable composite was placed in the prepared cavity, a piece of polyethylene fibre, that was dipped in bonding agent and blotted to remove excess solution was placed in the cavity with clean instrument, and covered entirely with flowable composite and then light cured.

Fig. 4. The remaining lost tooth structure was freehand built with microhybrid composite, and cured incrementally.

India Ltd. Mumbai, India) with long axis perpendicular to the base of the block. The restored samples were stored in 1% chloramine solution for 24 h before testing.

Measuring the fracture resistance of restored samples

The acrylic block containing the restored tooth was tightly fixed to the custom made inclined metal base to provide a 45° angle to the horizontal plane, which was held on the universal testing machine (Tinius Olsen, HT400, Horsham, USA). Compressive fatigue load was applied with loading tip of 2 mm cross-head diameter until failure occurred, at a speed of 1 mm min^{-1}, in the centre of the restoration on the palatal aspect with a relative angle of 135° to the palatal surface, with the aim of simulating the protrusive function (11). For control group, the load was applied at an area corresponding to the centre of restoration in other groups.

Stereomicroscopic evaluation for mode of fracture

The samples were then analysed for mode of fracture under stereomicroscope (Olympus, New York, NY, USA) at 3.5× magnification and were categorized as one of the two typical failure modes: adhesive fracture at tooth-restoration interface and cohesive breakage of the remaining part of tooth.

Statistical analysis

One-way ANOVA was used for multiple group comparisons followed by Tukey's test for group-wise comparisons. Fisher's exact test was used for analysis of mode of fracture.

Results

The mean fracture resistance and the standard deviation of the different group are shown in Table 1. Data from this table revealed that the highest mean fracture resistance was exhibited by control group (435.69 N ± 100.80) followed by fibre-reinforced composite (434.87 N ± 77.16) and nano composite (335.87 N ± 62.84). Microhybrid composite (241.60 N ± 52.59) showed the least fracture resistance. Multiple group comparison by one-way ANOVA revealed that the restorative materials and techniques significantly affected the fracture resistance among different groups ($P < 0.001$). Tukey's test revealed that the mean fracture resistance of fibre-reinforced composite and control group was significantly higher than microhybrid group and nano composite group, whereas an insignificant difference was observed among the control group and fibre-reinforced composite group, as well as among microhybrid group and nano composite group. Table 2 shows the mode of fracture among various samples of the test groups. Fisher's exact test revealed no statistical difference among the test groups.

Table 1. Comparison of fracture resistance between different groups

Study groups	No. of samples	Mean (in Newton) ± SD	Significance
Group A[a]	10	435.69 ± 100.80	$P < 0.001$*
Group B[b]	10	241.60 ± 52.59	
Group C[b]	10	335.87 ± 62.84	
Group D[a]	10	434.87 ± 77.16	

*Highly significant.
Identical superscript letters indicate no significant difference ($P > 0.05$).

Table 2. Mode of fracture among the test groups

	Group B	Group C	Group D
Adhesive fracture at tooth-restoration interface	8	8	5
Cohesive fracture within the remaining part of tooth	2	2	5

Thus, the results confirmed that the fibre reinforcement of the conventional composites has recovered the fracture resistance of the restoration comparable to the natural tooth.

Discussion

The present study was conducted to evaluate the fracture resistance of different composite materials and techniques used for incisal edge restoration of fractured maxillary central incisors. For this study, human upper central incisors extracted for periodontal problems were used. Inherent differences between specimens relate to external crown size, internal geometry (pulp chamber), enamel thickness and structure of dental tissues. Incisors of comparable external crown size were selected because the other variables could not be controlled. The tooth fracture is highly prevalent in younger individuals with larger pulp chambers, but the study assumed that the incisors available were originated from older patients, with reduction of pulp chamber sizes because of secondary dentinogenesis and gradual enlargement of the peritubular dentin with intratubular mineral deposits (5, 12, 13). However, the literature shows no significant differences in the microtensile bond strength of composite resins to the young and aged teeth (12, 14).

To simulate uncomplicated tooth fracture, the incisors were cut obliquely with a diamond disc rather than using an impact load which may lead to unpredictable fracture surfaces, causing differences in surface area, fracture location and direction.

Among the commonly used materials in the literature, porcelain veneering or porcelain jacket crown is with the disadvantage of being the operator sensitive, needs the intervention of a third person (technician), has higher cost and is also contraindicated in young children as they have a larger pulp chamber, with thinner dentin that may result in iatrogenic injury to the pulp (15). On the contrary, reattachment of the coronal fragment, if available, is a realistic alternative in terms of aesthetics. However, this technique recovered only 46% of fracture resistance as reported by Demarco et al. and others reported 50–80% loss of retention after 12–30 months (7, 16, 17).

Owing to the improvement in the aesthetic and physical properties of modern composite resins, they have become the material of choice for the direct anterior restoration but are not recommended for large restorations in regions with high masticatory forces (16, 18). On the other hand, FRC is a group of materials having high toughness and strength that has been used in many applications in dentistry. The fracture of the restoration may be the culmination of crack propagation in the restoration that was initiated by a flaw that was not detected or managed. In resin composite restorations, the fracture may also be a result of heavy masticatory loads placed on thin restoration (19).

The findings of this study indicate that microhybrid and nano composite groups showed significantly lower fracture resistance when compared to control group. Whereas, reinforcing the microhybrid composite with polyethylene fibre has recovered the fracture resistance comparable to the control group which is in agreement with the findings of the study by Garousi et al. (11, 16). This increase in the fracture resistance is the result of transfer of stresses from the weak polymer matrix to fibres that have a high tensile strength which dissipates the tension lines and internal microfissures that would cause catastrophic fracture in more rigid material (20). Forces that are parallel to the long axis of the fibre, however, produce matrix dominated failures and consequently yield little actual reinforcement. But, however, the polyethylene fibres (Ribbond THM; Ribbond Inc.) are not arranged longitudinally and are instead woven in alternating patterns would appear to increase the dispersion of the internal tension lines and thus, provide fracture resistance (9). It is suggested that placement of fibres at the tensile rather than at the compression side is most efficient for reinforcement (5, 21, 22). Hence, the fibres were placed as close to enamel as possible in the palatal cavity. Nano composite was found to have higher fracture resistance compared to microhybrid composite even though the difference was statistically insignificant, which correlated with the findings of Watanabe et al. (19). This showed that in spite of change in the filler size and concentration, the resin matrix has failed to achieve fracture resistance of natural tooth.

Eight samples among the microhybrid composite and nano composite group showed adhesive failure at tooth-restoration interface with flecks of restorative material remaining at the tooth surface, whereas two samples exhibited partial chipping of the enamel. Among FRC group, five samples exhibited complete adhesive failure, whereas four samples exhibited partial chipping of enamel as well as the dentin and one sample fractured at the cervical region of the tooth. The mode of fracture among the test groups was statistically insignificant. Among the test groups, adhesive failure or cohesive fracture within the restoration without fracture of tooth material was expected. This was the case for microhybrid and nano composite groups. Increased fracture resistance of the fibre-reinforced group, however, was combined with a higher risk of tooth substrate fracture. A possible reason is the higher toughness of the fibres and the additional anchorage from the palatal surface for the fibre placement. The different failure modes of repair with conventional technique were reported in the literature. These differences may partly be explained by difference in the loading technique. In some studies, the tooth was loaded at 90° angle (23, 24), whereas in this study, the tooth was loaded to more closely simulate the clinical condition of 135° angle.

When evaluating the results of this investigation, it must be noted that there may be limitation to the direct application of in vitro results to in vivo situation which include lack of thermocycling and water storage. The specimens were tested in dry conditions without thermocycling as this study was intended to measure the reinforcing effect of fibre on the composite material. Obviously, the well-known plasticizing influence of water storage and thermocycling on the FRC should be taken into account (25). The influence of water storage and thermocycling on fracture propagation characteristics needs to be investigated.

Conclusion

Fibre-reinforced composite used for the restoration of fractured incisal edge has achieved the fracture resistance almost equal to intact natural tooth. This may help to optimize properties of directly made composite restorations in anterior teeth.

References

1. Ries A, Loguercio AD, Kraul A, Matson E. Reattachment of fractured teeth: a review of literature regarding technique and material. Oper Dent 2004;29:226–33.
2. Kahabuka FK, Mugonzibwa EA. Risk factors for injuries to maxillary permanent incisors and upper lip among school children in Dar es Salaam, Tanzania. Int J Paediatr Dent 2009;19:148–54.
3. Baldava P, Nagaraj A. Risk factors for traumatic dental injuries in an adolescent male population in India. J Contemp Dent Pract 2007;8:1–10.
4. Gandhi K, Nandlal B. Effect of enamel preparations on fracture resistance of composite resin buildup of fractures involving dentine in anterior bovine teeth: an in vitro study. J Indian Soc Pedod Prev Dent 2006;24:69–75.
5. Fennis WMM, Kruelen CM, Wolke JGC, Fokkinga WA, Machado C, Creugers NHJ. Fracture resistance reattached fragments with mini fibre-reinforced composite anchors. J Dent 2009;37:462–7.
6. Anca Silvia Valceanu. Ultraconservative and Minimally Invasive Esthetic Restoration of Crown Fractures: case Report. J Cosm Dent 2006;22:100–7.
7. Demarco FF, Fay RM, Pinzon LM, Powers JM. Fracture resistance of re-attached coronal fragments – influence of different adhesive materials and bevel preparation. Dent Traumatol 2004;20:157–63.
8. Sengun A, Ozer F, Unlu N, Ozturk B. Shear bond strength of tooth fragments reattatched or restored. J Oral Rehab 2003;30:82–6.
9. Vitale MC, Caprioglio C, Martignone A, Marchesi U, Botticelli AR. Combined technique with polyethylene fibers and composite resins in restoration of traumatized anterior teeth. Dent Traumat 2004;20:172–7.
10. Arhun N, Arman A. Fiber-reinforced technology in multidisciplinary chairside approaches. Indian J Dent Res 2008;19: 272–7.
11. Garousi SK, Ballo AM, Lassila LVJ, Vallittu PK. Fracture resistance of fragmented incisal edge restored with fibre reinforced composite. J Adhes Dent 2006;8:91–5.
12. Giannini M, Chaves P, Oliveira MTD. Effect of tooth age on bond strength to dentin. J Appl Oral Sci 2003;11:342–7.
13. Nalbadian J, Gonzales F, Sognnaes RR. Sclerotic age changes in root dentin of human teeth as observed by optical, electron and x-ray microscopy. J Dent Res 1960;39:598–607.
14. Brackett WW, Tay FR, Looney SW, Ito S, Haisch LD, Pashley DH. The effect of subject age on the microtensile bond strengths of a resin and a resin-modified glass ionomer adhesive to tooth structure. Oper Dent 2008;33:282–6.
15. Bambilla GPM. Fractured incisors: a judicious restorative approach – part 2. Int Dent J 2007;57:100–8.
16. Garousi SK, Lassila LVJ, Vallittu PK. Fatigue strength of fragmented incisal edges restored with fibre reinforced restorative materials. J Contemp Dent Pract 2007;8:009.
17. Andreasen FM, Noren JG, Andreasen JO, Engelhardsten S, Lindh-stromberg U. Long-term survival of fragment bonding in treatment of fractured crowns: a multicentre clinical study. Quint Int 1995;28:669–81.
18. Fortin D, Vargas MA. The spectrum of composites: new techniques and materials. J Am Dent Assoc 2000;131:26S–30S.
19. Watanabe H, Khera SC, Vargas MA, Qian F. Fracture toughness comparison of six resin composites. Dent Mater 2008;24:418–25.
20. Vallittu PK, Lassila VP, Lappalainen R. Transverse strength and fatigue of denture acrylic-glass fiber composite. Dent Mater 1994;10:116–21.
21. Ellakwa AE, Shortall AC, Shehata MK, Marquis PM. The influence of fibre placement and position on the efficiency of reinforcement of fibre reinforced composite bridgework. J Oral Rehabil 2001;28:785–91.
22. Dyer SR, Lassila LV, Jokinen M, Vallittu PK. Effect of fiber position and orientation on fracture load of fiber-reinforced composite. Dent Mater 2004;20:947–55.
23. Eid H, White GE. Class IV preparation for fractured anterior teeth restored with composite resin restoration. J Clin Pediatr Dent 2003;27:201–11.
24. Farik B, Munksgaard EC, Andreasen JO, Kreiborg S. Drying and rewetting anterior crown fragments prior to bonding. Endo Dent Traumatol 1999;15:113–6.
25. Vallittu PK Effect of 180-weeks water storage on the flexural properties of E-glass and silica fibre acrylic resin composite. Int J Prosthodont 2000;13:334–9.