ORIGINAL ARTICLE

Comparative Evaluation of the Fracture Resistance of Simulated Immature Teeth Reinforced with a Novel Anatomic Post and MTA or Biodentine as an Apical Barrier: An *In Vitro* Study

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Abstract

Aim: To evaluate and compare the resistance to fracture of simulated human immature teeth treated with MTA/Biodentine as apical barrier, reinforced with a novel anatomic post.

Materials and methods: Eighty extracted maxillary central incisors were used in this study. Access opening was done, and ProTaper rotary instruments up to F3 were used to prepare the root canal. Peeso reamers were used sequentially up to size 6 (1.7 mm) with 1 mm beyond the apex to simulate immature teeth. Irrigation with 2.5% sodium hypochlorite (NaOCl) and 17% ethylenediaminetetraacetic acid (EDTA) was done. They were then divided into two groups ($n = 40$ each) according to the apical barrier used for apexification: group I—apical barrier using Biodentine and group II—apical barrier using MTA. Each group was then divided into four subgroups: subgroup A ($n = 10$)—apical barrier using Biodentine/MTA with no obturation, subgroup B ($n = 10$)—apical barrier using Biodentine/MTA with everStick post as reinforcement, subgroup C ($n = 10$)—apical barrier using Biodentine/MTA with complete filling using the same material used for apical barrier, and subgroup D ($n = 10$)—apical barrier using Biodentine/MTA with prefabricated glass fiber post as reinforcement. All samples were incubated for two weeks at 37°C before subjecting to fracture testing using the Universal Testing Machine. A compressive load was applied at 135° to the long axis of the tooth.

Results: Statistical analysis was done using one-way ANOVA test and *post hoc* Bonferroni test. In the above tests, p value less than 0.05 ($p < 0.05$) was taken to be statistically significant.

Conclusion: A novel anatomic post, everStick post is a viable option for reinforcement of teeth with immature root apex and thin dentinal walls after apexification.

Keywords: Anatomic post, Apexification, everStick post, Immature teeth, Reinforcement.

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Introduction

Traumatic dental injuries are common in children aged between 8 years and 12 years, and the maxillary incisors are the most frequently affected teeth. A traumatic impact on the immature anterior teeth may lead to pulp nonvitality, resulting in arrested root development. The endodontic treatment of such teeth with necrotic pulps poses a challenge because of the open apices, and the thin dentinal walls predispose teeth to fracture.[1,2]

Cervical third root fractures have an occurrence rate of about 28–77%, the highest percentage of fractures occurring in immature teeth.[3] There has been a paradigm shift in the way necrotic immature permanent teeth are being treated.

An optimal treatment protocol for immature permanent teeth with necrotic pulp is to regenerate functional pulp tissue and facilitate continuation of root development and apical closure. Although it has potential for clinical success, it may not be successful in every case. It requires strict adherence to treatment protocol and takes longer time for completion of treatment, and possible failure may make further treatment difficult.[4] Apexification is considered as one of the effective treatment modalities for non-vital immature permanent teeth. It commonly involves the orthograde placement of an artificial apical barrier of mineral trioxide aggregate or Biodentine. Even though placement of an apical barrier expedites the apexification procedure, it does not reinforce the thin-walled roots. Hence, the susceptibility to fracture may remain unaltered after the treatment.[5]

Ultimately, the restoration of immature teeth after apexification should strengthen the weak root and maintain the tooth in function.[6] Although AAE has recommended that posts are used to retain core, efforts are being made to use the posts to reinforce weakened immature teeth.[7]

The traditional obturating material, gutta-percha, when used with an apical barrier does not reinforce such teeth adequately; hence, new materials are being tested to reinforce immature teeth.[8–10]

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Historically, customized metal posts were widely used to reinforce immature teeth, due to their superior mechanical properties. However, multiple appointments, temporization, probability of contamination, possible casting procedure limitations and defects, and discoloration of the tooth over a period of time make the procedure difficult.[11–13] Hence, these disadvantages make use of metal posts a less preferred option in immature teeth. Introduction of all ceramic full-coverage restorations require a more esthetic substrate dowel material. Hence, restoration of such teeth with improved optical and physical properties is a major objective during treatment.[14] As an alternative, glass fiber posts which exhibit a modulus of elasticity similar to that of the dentin has been investigated extensively. They are less expensive and easier and faster to fabricate and has easy retrievability.

But the disadvantage of using prefabricated fiber post in wide immature root space is that it does not ensure complete interfacial adaptation to the root dentin wall. They require shaping of the canal walls to fit the dowels, leading to dentin loss, and increase the incidence of root cracks and fractures.[15]

The problems with reinforcement of over-flared canal can be solved by a novel, direct, and anatomically adjustable glass-fiber-reinforced everStick post. This post is a polymer of polymethyl methacrylate and resin-impregnated bisphenol A–glycidyl methacrylate uncured glass fiber post. It is soft and flexible and hence can be customized and closely adapted to flared, oval, and curved morphology of the root canal. Their flexural strength and elasticity are nearly similar to dentin. Thus, an equal distribution of occlusal stresses along the root surface will evenly minimize the risk of root fracture.[16]

Fewer studies have so far compared the fracture resistance of teeth reinforced with MTA and Biodentine and also used everStick post as a viable reinforcement material. Therefore, this study is aimed to evaluate the fracture resistance of simulated human immature teeth treated with MTA/Biodentine apical barrier, reinforced with glass fiber post and a novel anatomic post.

Materials and Methods

Specimen Preparation

A total of 80 freshly extracted human maxillary central incisors, extracted due to periodontal reasons, were used in the current study. Coronal access was made using a size 3 round bur and an Endo Z bur (Dentsply, India). The root canals were prepared using ProTaper rotary instruments (Dentsply, India) up to F3. The canals were instrumented with Peeso reamers (size 1–6) (Mani, Inc) until size 6 (1.7 mm) which could be passed 1 mm beyond the apex to simulate immature teeth. The root canals were irrigated using 3 mL 2.5% sodium hypochlorite (NaOCl) after each instrument, and a final flush with 5 mL 17% ethylenediaminetetraacetic acid (EDTA) was carried out to remove the smear layer. Finally, the root canals were rinsed with distilled water and dried using paper points.

The eighty teeth were then randomly divided into two groups ($n = 40$) according to the apical barrier used for apexification:

Group I—apical barrier using Biodentine (Septodont, India)

Group II—apical barrier using MTA (MTA Plus)

Each group was further divided into four subgroups:

Group I ($n = 40$)

Subgroup A ($n = 10$)—apical barrier using Biodentine with no obturation (Fig. 1, subgroup IA).

Subgroup B ($n = 10$)—apical barrier using Biodentine with everStick post as reinforcement (Fig. 1, subgroup IB).

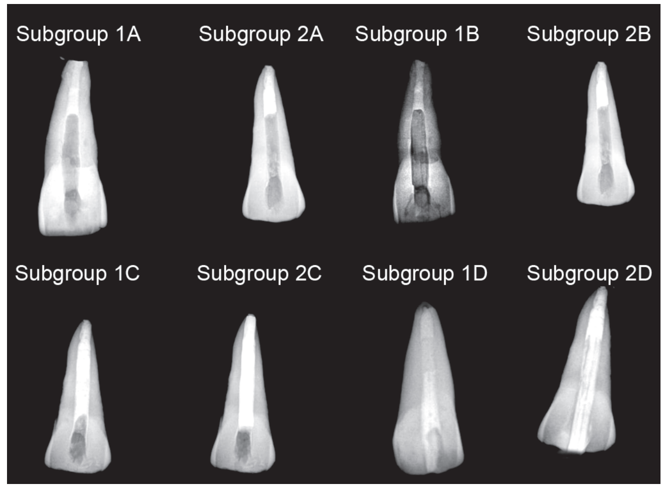

Fig. 1: Images showing the various subgroups

Subgroup C ($n = 10$)—apical barrier using Biodentine and the same Biodentine as complete obturation material (Fig. 1, subgroup IC).

Subgroup D ($n = 10$)—apical barrier using Biodentine with prefabricated glass fiber post as reinforcement (Fig. 1, subgroup ID).

Group II ($n = 40$)

The subgroups ($n = 10$ each) were same as Group I, but Biodentine was replaced by MTA as apical barrier as well as canal reinforcement material (Fig. 1, subgroups IIA, IIB, IIC, IID)

The groups are explained in Flowchart 1.

MTA Apexification

MTA Plus powder was mixed with distilled water in a proportion of 3:1 according to the manufacturer's instructions. It was placed into the canals using cement carrier, introduced 3 mm short of the working length and condensed apically by gentle packing with hand pluggers (Dentsply Maillefer) to obtain a 4-mm apical plug, while the canal at its apical end was closed with a moistened cotton pellet to simulate clinical conditions and to prevent material extrusion during barrier placement. A moistened paper point was left in the canal to facilitate the proper setting of the material, and access cavities were sealed with cotton pellet and Cavit. After 24 hours, Cavit, cotton pellet, and the paper point were removed and a finger plugger was introduced to test proper setting of MTA. This was done for all the forty samples in the group and then divided into different subgroups for reinforcement.

Biodentine Apexification

Biodentine (Septodont, India) liquid from a single-dose container was emptied into a powder-containing capsule and mixed for 30 seconds in an amalgamator according to the manufacturer's instructions. Biodentine was then placed with a carrier and adapted to the canal walls using a hand plugger to obtain a 4-mm apical plug. This was done for the rest of the forty samples and then divided into different subgroups for reinforcement.

The teeth were stored at 37°C and 100% humidity for 1 week, and then radiographs were taken to assess the quality of the apical plug.

Intraradicular Reinforcement

In subgroup A, no intraradicular reinforcement was provided. It served as a negative control group.

Flowchart 1: Division of groups and subgroups

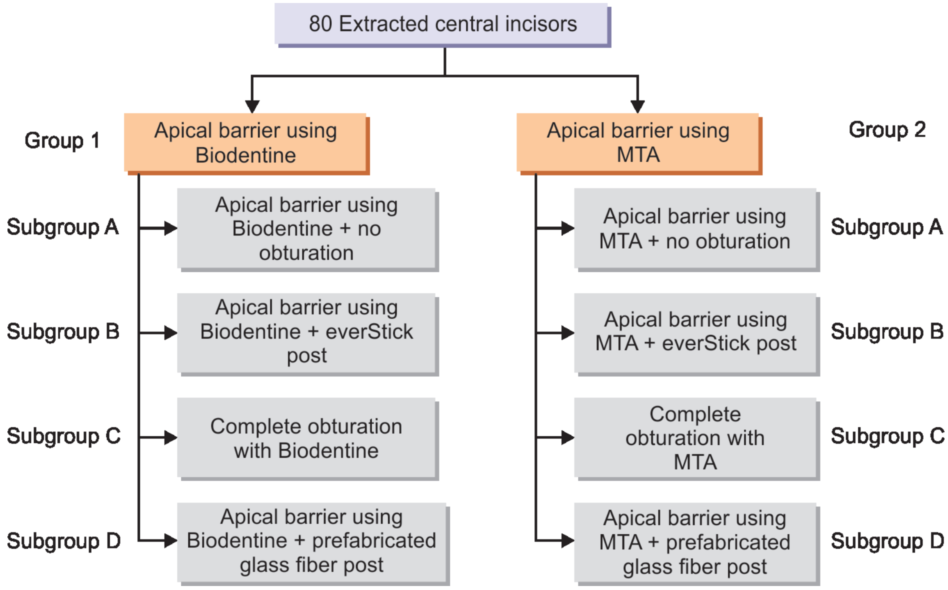

Table 1: Intergroup comparison of the fracture resistance of the simulated human immature teeth treated with MTA and Biodentine apical barrier with various obturation techniques

Experimental groups	*MTA apical barrier*	*Biodentine apical barrier*	*p value (unpaired t test)*
Control	618.08 ± 12.83	646.49 ± 11.50	<0.001*
everStick post	1297.90 ± 41.43	1482.94 ± 29.37	<0.001*
MTA/Biodentine obturation	727.25 ± 13.48	815.00 ± 11.47	<0.001*
Fiber post	1014.73 ± 17.77	1025.31 ± 13.32	0.150

*$p < 0.05$ is statistically significant

In subgroup B, the intraradicular reinforcement was done using a novel anatomic post, everStick Post (GC India). The everStick post of 1.2 mm diameter was taken out from the foil bag; the required post length was cut from the silicone strip using scissors, and the foil bag was closed with its sticker. The post was then carried to the canal with the help of a tweezer, and its fit was checked at the length measured by the file. The spreader was then inserted to see whether any space was left for an additional post. It was taken out and light-cured for 10 seconds. The hardened post was then inserted to ensure its snuggly fit. The canal was then filled with Stick Resin with an intraoral tip, and the post was slowly inserted. The coronal part of the material was spread in a fan shape which acted as a core for better retention of composite restoration.

In subgroup C, MTA/Biodentine, according to the groupings, was placed incrementally into the root canal to the level of CEJ.

In subgroup D, a prefabricated fiber post was bonded using total etch technique, universal bonding agent, and a dual-cure composite resin cement and light-cured for 15 seconds.

All samples were incubated for two weeks at 37°C and mounted on cold-cured acrylic resin before subjecting to fracture testing using the Universal Testing Machine.

Fracture testing

A compressive load was applied at 135° to long axis of the tooth above the cingulum with a stainless steel chisel-shaped tip at a crosshead speed of 0.5 mm/min until fracture. Load to fracture of each sample was recorded in Newton, and fracture pattern was examined.

Statistical Analysis

Descriptive statistics were expressed as means and standard deviations for each group. Within-group comparisons for the fracture resistance of the simulated human immature teeth were mad using on-way ANOVA test and *post hoc* Bonferroni test. Intergroup comparison was made using unpaired Student's *t* test. In the above tests, *p* value less than 0.05 ($p < 0.05$) was taken to be statistically significant.

Results

- The results of this study showed that groups with Biodentine showed significantly higher fracture resistance compared to groups with MTA (Table 1).
- *Post hoc* Bonferroni test showed greater resistance to fracture in groups reinforced with everStick posts compared to other reinforcement materials (Figs 2 and 3).
- The study showed less fracture resistance in groups obturated completely with MTA and Biodentine (Figs 2 and 3). But Biodentine obturation showed significantly better fracture resistance compared to MTA obturation (Table 1).
- The level of fracture line for subgroups A and C was apical to CEJ. For subgroup B with anatomic post, the teeth fractured coronal

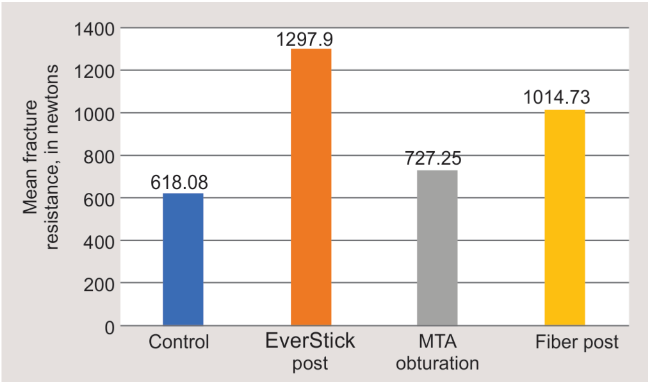

Fig. 2: Comparison of the fracture resistance of the simulated human immature teeth treated with MTA apical barrier and various obturation techniques

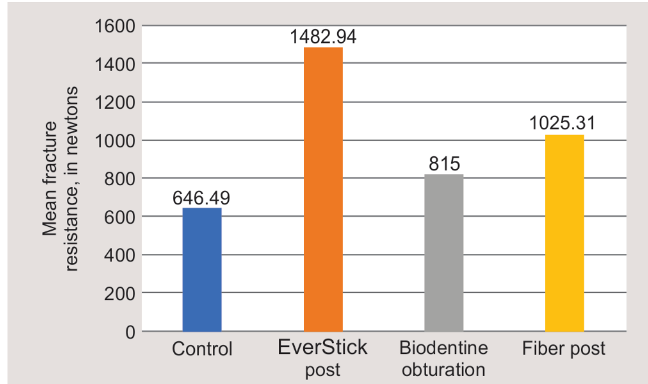

Fig. 3: Comparison of the fracture resistance of the simulated human immature teeth treated with Biodentine apical barrier and various obturation techniques

to CEJ. The teeth reinforced with glass fiber post in subgroup D showed fracture line at CEJ.

Discussion

Susceptibility of fracture of endodontically treated immature teeth depends on their stage of root development, which is directly related to the remaining dentin wall thickness and root length.[3] Attempts are being made to assess the use of custom-made posts, glass fiber post in reinforcement. Hence, this study was undertaken to check fracture resistance and mode of failure of reinforced immature permanent central incisors. Only maxillary central incisors were selected as they are susceptible to trauma and external impact due to their position in oral cavity.[17] Several studies have shown that the enlargement of the internal diameter of the root canal of mature root to the size of 1.75 mm can mimic the morphology of an immature root. Hence, Peeso reamers up to number 6 were used to mimic the immature root apex in this study.

As the dentin wall thickness decreases, the resistance to fracture decreases as well, and therefore, it is important to select a material that can reinforce the root structure.[4,18] All posts in this study were cemented with resin as it increases the fracture resistance of reinforced teeth.[19] It increases the capacity of post adhesion and shows greater toughness and longevity, low solubility, and minimum microfiltration as compared to conventional cement.[20,21]

MTA/Biodentine apexification and root filling with gutta-percha, and AH Plus sealer did not provide increased strength to the simulated immature teeth; this agrees with other studies.[8,9,18] The gutta-percha has a lower modulus of elasticity in comparison with dentin, 0.074–0.079 and 14.0–18 GPa, respectively.[22] Filling the access cavity with composite resin does not provide reinforcement effect to the cervical area of the root.

The control group showed the least fracture resistance, confirming that reinforcement of unfilled immature root apex is important.

Instead of creating a 4-mm plug of MTA as a barrier, several researchers have proposed the filling of the entire root canal with MTA. The rationale is that the modulus of elasticity of MTA (15–30 GPa) is similar to that of dentin (14.0–18.6 GPa).[22] Formation of a hydroxyapatite-like layer has been found between MTA and dentin, which suggests the chemical bonding between them.

The group with complete obturation with Biodentine showed significantly higher fracture resistance than the group obturated with MTA because with MTA has a tensile strength of 9.5 MPa, while that with Biodentine has a tensile strength of 16 MPa. The faster setting of Biodentine has been attributed to its setting accelerator which improves its handling properties and strength. This is an advantage over MTA, as delayed setting time, as studied by Torabinejad M et al., leads to a higher risk of partial material loss and alteration of the interface during the finishing phase of the procedure.[23–25] Therefore, Biodentine has a great improvement compared to MTA in terms of setting time.

During the setting of Biodentine, the compressive strength increases 100 MPa in the first hour and 200 MPa at 24th hour and it continues to improve with time over several days until reaching 300 MPa after one month,[25] which is comparable to the compressive strength of natural dentine, i.e., 297 MPa. A study by Grech L et al. showed that due to the low water/cement ratio used in Biodentine, a higher compressive strength was seen when compared to other tested materials.[25]

This study was done and tested over a period of 3 weeks, and the results obtained showed favorable results for subgroup IC compared to subgroup IIC with increased fracture resistance of the teeth due to the materials used. But, the long-term studies such as of Sawyer et al.[23] who examined whether prolonged contact of dentin with two recently introduced calcium silicate-based materials, Biodentine and MTA, adversely affects flexural properties. They stated that dentin flexural strength exposed to Biodentine decreased significantly after 2 and 3 months, whereas that exposed to MTA decreased significantly after 3 months of aging. Furthermore, they stated that the fracture resistance of roots will probably not be adversely affected when these calcium silicate-based materials are used as apical plug material. However, the practice of completely obturating root canals with these new calcium silicate-based materials may decrease the fracture resistance of teeth over time. This is because these materials release highly alkaline calcium hydroxide, which induces a caustic degradation effect on exposed collagen, and this is mediated by the breakdown of intermolecular bonds in collagen fibrils, increasing their water absorption leading to swelling.[26] The fracture resistance of the material increases when tested at the end of three weeks in this study due to which there were favorable results expected in subgroups IC and IIC, but may decrease the fracture resistance of the tooth significantly over 3 months when used as complete obturation material. This concludes that the use of MTA or Biodentine as a complete obturating material is not advisable and a better reinforcement material is required to favor the resistance to fracture of teeth.

The group reinforced with everStick post showed significantly greater fracture resistance compared to the other reinforcement materials. The post which is initially pliable hardens upon polymerization with light. The unpolymerized form allows the resin monomer at the surface to chemically react with monomers in the resin cement.[27] The monoblock components behave as one unit under functional forces, with improved distribution of stress and greater resistance to fracture. In addition, several factors might influence the mechanical properties of FRC posts, such as the type of polymer matrix, length, diameter, number, and fiber orientation of embedded fibers.[28] Thus, the presence of a high molecular weight polymethyl methacrylate chains in the everStick post acts as stress breaker via plasticizing the stiffness of highly cross-linked bisphenol A–glycidyl methacrylate matrix, decreases stress concentration at the interface of fiber matrix during deflection, and absorbs the emerging stresses through the matrix.[27] Also, during manufacture of FRC posts, the rehabilitating effect of unidirectional impregnated fibers can be created. These impregnated fibers are soaked with resin matrix in a prestressed tension that is released after curing, causing fibers to compress, which can absorb the tensile stresses under flexural forces.[29] Moreover, these fibers facilitate stress dissipation, support the fillers of composite layers, and act as a crack stopper.[29,30] The more the increase of fibers in the matrix, the more increase in the post's resistance to microcracking.[31]

The groups reinforced with fiber posts showed better fracture resistance compared to complete obturation with MTA/Biodentine. The fiber post distributes stresses evenly along the tooth structure and has a modulus of elasticity similar to dentin. But a prefabricated fiber post in a blunderbuss canal shows less adaptation to the root dentin compared to an anatomic post, which may be the reason it showed less resistance to fracture compared to group reinforced with everStick post. This result is in agreement with a study done by Beltagy et al.[32] who stated that the unidirectional fibers in everStick post distributed the stresses more evenly compared to a prefabricated fiber post.

The type of fractures seen after the load was placed over the samples was of two types: favorable fractures (coronal to CEJ) and unfavorable fractures (apical to CEJ). In this study, 7 out of the total 20 samples of fiber post group showed oblique to horizontal fractures at CEJ, while 4 out of 20 samples of everStick post showed oblique to horizontal fractures coronal to CEJ. A study done by Linsuwanont et al.[6] supported this result related to the fiber post groups. This depicted that the samples showed restorable fractures in everStick post groups. In rest of the groups (subgroups A and C) all the tested samples showed oblique to horizontal fractures apical to CEJ. This concluded that pulpless immature teeth are highly susceptible to cervical fractures unless the teeth are not reinforced with suitable materials.

Conclusion

Reinforcement of immature permanent teeth with thin dentinal walls is as important as placing an apical barrier to expedite apexification. The use of adhesive fiber posts is the new advancement toward it. The everStick posts are a viable treatment option with promising results. Further long-term clinical studies are required and desirable to support such *in vitro* studies.

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