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Reinforcing an immature tooth model using three different restorative materials

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ABSTRACT

Background: To compare and evaluate the strength rendering capacity of three restorative materials in tooth model simulated as immature teeth.

Materials and Methods: In this *in vitro* study, 80 human maxillary permanent central incisors scheduled for periodontal extraction were collected, and an immature tooth model was prepared using a 3 mm twist drill. To simulate single-visit apical barrier, all the teeth were prepared with peso number 1–6. The teeth were segregated into three experimental and a control group. The experimental groups (n = 20) comprised of fiber-reinforced composite (FRC), Biodentine, and glass ionomer cement. The fracture resistance of all the teeth was tested using universal testing machine. The final reading of the applied load to cause fracture was noted and later was subjected to statistical analysis, $P \leq 0.05$ was considered statistically significant, and the level of significance was fixed at 5%. Student's t-test was applied to compare values among experimental groups

Results: There was a significant difference in the values of peak load resulting in fracture among experimental groups which was observed statistically ($P \leq 0.001$). FRC exhibited superior reinforcing capacity (mean: 1199.7 N) among the experimental materials followed by Biodentine and Bioglass R. The lowest value to fracture was observed in control group (mean: 236.7 N).

Conclusion: The results indicate that FRC could substantially contribute positively in reinforcing the simulated thin-walled immature roots.

Key Words: Biodentine, glass ionomer cement, reinforced composite

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INTRODUCTION

Loss of the tooth structure or tooth could be due to various dental causes such as caries, noncarious lesions, trauma, and periodontal diseases. Among the entire causes, dental trauma is the most common reason leading to tooth destruction in the age group of 2–18 years.

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The frequent reason resulting in dental injuries are accidents owing to violating traffic rules, unexpected injuries during playing a sport and violent acts. Various literatures suggest that the maxillary anterior teeth are usually the most affected teeth in dental impact injuries, affecting the tooth during root

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developmental stages rendering them nonvital and more prone to fractures.[1-3]

Traumatic injuries to young permanent tooth pose a problem to the clinician since such teeth are prone to fracture due to secondary injuries such as minor trauma or occlusal loading during mastication, often resulting in nonrestorability of the tooth which accounts to 28%–77% depending on the stage of root development.[3,4]

Recent improvements in root end restorative materials and the techniques adapted to address the open apex have helped the clinicians to achieve an apical barrier. There are various treatment modalities mentioned in the literature regarding open apex in immature teeth, namely apexification, apexogenesis, revascularization, and regeneration. The single-step apical barrier placement has an advantage of shorter treatment time, which could positively help the clinician in addressing the thin dentinal wall at the cementoenamel junction (CEJ) by reinforcing the weakened area of the root.[5]

Various studies that have been reported vary regarding the choice of restorative material to strengthen and cover the rest of the cervical third of root. With the emergence of innovative expertise, researches are focused on inventing materials that impart strength to the weakened cervical third of root structure.[5-8]

The study was conducted to evaluate and compare the strength rendering capacity of three restorative materials in a simulated immature teeth model.

The null hypothesis was that no difference would be observed between fiber-reinforced composite, bio dentine, and glass ionomer cement (GIC) in reinforcing the immature permanent teeth

MATERIALS AND METHODS

In this *in vitro* study, 80 human maxillary permanent central incisors scheduled for periodontal extraction were collected from the patients attending outpatient department of the Department of Oral and Maxillofacial Surgery at Sri Aurobindo College of Dentistry, Indore, India.

The inclusion criteria for the study were noncarious maxillary central incisors indicated for periodontal extraction, single root and single canal, and teeth withcomplete root formation (confirmed using radiovisiography).The mesiodistal dimension was considered at 6.68 ± 1 mm and buccolingual dimension at 6.40 ± 1 mm (for standardization) using Vernier caliper.

The exclusion criteria were teeth with two or more canals, cracks and fracture line, calcification, roots with aberrant anatomy, open apices, and teeth with previous endodontic treatment (confirmed using radiovisiography)

Preparation of samples

Immature tooth simulation

The standardization of the experimental tooth was done by limiting the tooth length to 13 ± 1 mm as measured from the apex of the root to the facial CEJ of the crown using Corborundum Disk (Dentorium, New York, NY, USA) mounted on Straight Handpiece (NSK, Tokyo, Japan). To simulate immature tooth, the root of each experimental tooth was prepared with peso reamer number 1–6 (Mani, Tochigi, Japan) I mm beyond the apical limit after following the routine protocol of biomechanical preparation.

Simulation of Cvek's Stage III

Simulation of Cvek's Stage III was done using a Stainless Steel Twist Drill (Indo Global Engineering Machine, Mumbai, India) of 3 mm diameter which extended 3 mm below the facial CEJ. The 3 mm diameter drill was chosento achieve a 1:1 root-to-canal ratio at the CEJ. The experimental teeth were radiographed later to check the thickness of remaining dentin [Figure 1].

Simulation of single visit apical barrier placement

Simulation was done by placing 4–5 mm bio dentine apically using Schilder carrier. All teeth were maintained in flower arrangement sponge and placed in incubator (100% relative humidity) to simulate oral conditions. Thermoplastisized gutta-percha (ObturaII, Kerr, USA) with AH Plus (DentsplyMaillefer, Konstanz, Germany) was used for obturation of canal 5 mm coronal to Biodentine leaving 3 mm coronal third of root canal, which was later filled with the experimental restorative materials [Figure 1].

Reinforcement of coronal part of root (Cvek's Stage III)

Group I: Fiber-reinforced composite (FRC) (Everx posterior, GC, Europe)

The coronal third of the roots of simulated immature teeth (n = 20) were reinforced with FRC (coronal 3 mm of root) and condensed by precisely following the manufacture's instructions. The entire access cavity was sealed with FRC, and the teeth were later kept in flower arrangement sponge to prevent the dehydration [Figure 1].

Group II: Biodentine (Septodont, France)

Biodentine was mixed in an amalgamator as per the manufacturer's instruction and was filled in each specimen (n = 20) in coronal third of the root. The final coronal seal was done using composite resin (Z250, 3M, Mumbai, India) [Figure 1].

Group III: Glass Ionomercement (Biodynamica, Brazil)

Bioglass R was mixed according to the manufacturer's instruction and was filled in the coronal third of each canal (n = 20). The endodontic cavity was later sealed by composite resin (Z250, 3M, Mumbai, India) as the final restoration [Figure 1].

Group IV: (Control group)

Teeth were instrumented (n = 20), but neither obturated nor reinforced which served as a control group.

Mounting of prepared samples

A customized stainless steel mold was fabricated with a dimension 15 mm × 15 mm and was used for mounting the prepared tooth samples using cold cure acrylic resin. To simulate the average thickness of the periodontal ligament, the radicular part of prepared samples (2 mm below CEJ) was bordered with thin single sheet of spacer wax (0.3 mm thickness).

Each tooth was removed from the resin block after initial polymerization. The spacer wax was removed from the root surface, and alveolus of the acrylic resin block and an injectable vinyl polysiloxane impression material (virtual light body: Ivoclarvivadent, Mumbai, India) was delivered into the acrylic resin alveolus.

To achieve a flat surface, excess silicon material was removed, 2 mm below the CEJ of each tooth. The entire block of acrylic resin was removed gently and was finished and polished using the acrylic trimmer [Figure 2].

The samples were stored in 100% relative humidity in incubator until subjected to fracture resistance under universal testing machine (UTM) (DIDAC International, Mumbai, India).

Fabrication of triangular jig

A triangular jig with a hollow tube was fabricated to provide space for the acrylic block to be fixed. The acrylic block with the mounted experimental teeth was subjected to fracture resistance testing using UTM machine at an angle of 130° [Figure 3].

Testing of samples under universal testing machine

Fracture resistance of all experimental teeth was tested using the UTM at 5 mm/min cross speed. The load was applied with a 3 mm chisel-shaped metallic

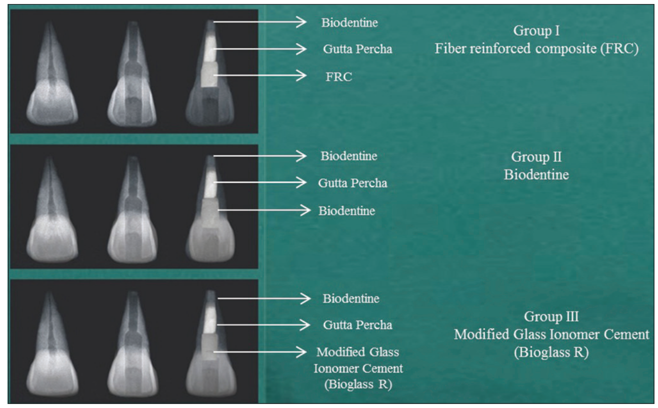


Figure 1: Simulation of immature tooth and reinforcement of cervical third of root.

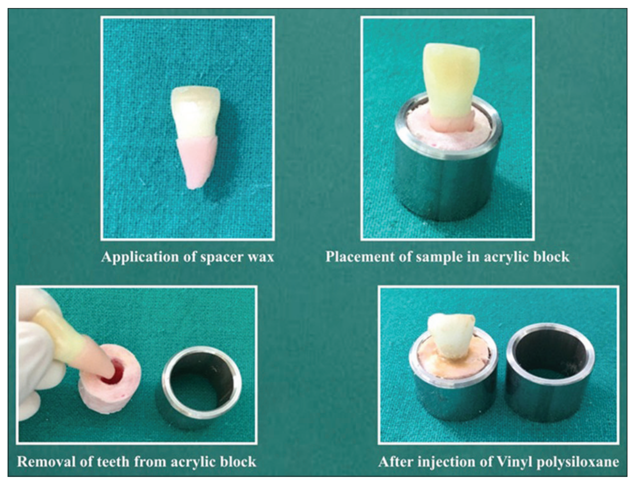


Figure 2: Sample reparation procedure.

Figure 3: Fracture resistance testing of immature tooth using universal testing machine at an angle of 130°.

device palatally at the level of CEJ [Figure 2]. All the data were recorded in Newton (N) from the first point of application till the first fracture point that was represented by a sudden drop of load.

Statistical analysis

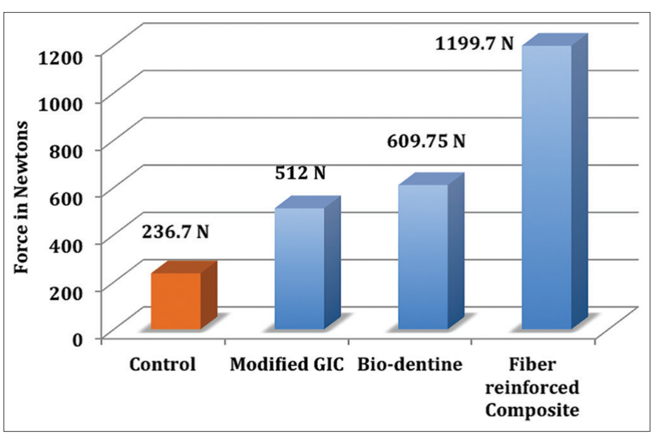
Statistical analysis was done using package for social sciences (SPSS, IBM version 20.0, Chicago, USA), $P \leq 0.05$ was considered statistically significant, and the level of significance was fixed at 5%. Descriptive statistics was applied in the study. Comparison of mean peak load required to cause cervical fracture among the groups was performed using Student's t-test. The roots reinforced and strengthened with FRC exhibited highest load for fracture (mean: 1199.7 N), whereas the control group exhibited the lowest value for fracture (mean: 236.7 N) [Graph 1].

The results indicate a highly substantial difference in load required to cause cervical fracture among the experimental groups and the control group ($P \leq 0.001$). All the experimental groups showed to have better reinforcement and strengthening qualities compared to the control group [Table 1].

FRC exhibited superior reinforcing capacity among the experimental materials followed by Biodentine and Bioglass R.

DISCUSSION

Most of the endodontic cases can be managed as expected and contentedly, still there exist a set of patients that defy expectable routine treatment. This group comprises of those who present immature teeth with divergent and insubstantial dentinal thickness and their susceptibility to fracture predominantly at the cervical third and recurrent periapical lesions.[1-4]



Graph 1: Meanpeak load required to causecervical root fracture.

Therefore, the present study was conducted to assess the fracture resistance of replicated immature teeth restored with different experimental restorative materials. Retrospective clinical studies demonstrated that the rate of cervical fracture was dependent on the stage of root development when restored with various restorative materials.[4,9-11]

Cvek (1992) classified immature teeth according to the level of root maturity (less than half, half, two-third and more than two-third),[12] as well as reported the percentage of risk fractures according to the root development stages. Studies conducted in the past considered Stage III development of Cvek's classification in their *in vitro* study.[4,10]

In the present study, the open apex was simulated using the peso number 1–6. The peso number 6 has diameter of 1.7 mm. Cvek's Stage III was simulated using the engineering twist drill having diameter of 3 mm which corresponds to 1:1 root dentine ratio. Cevk's Stage III was chosen because, in Stage I the shorter roots (4–5 mm) were easily displaced from the acrylic blocks during loading. In Stage IV and V a canal diameter of 1.5 mm or less may be present, which may not be susceptible to fracture, therefore may not require reinforcement. Hence, the present study considered a canal diameter of 3 mm for evaluating the reinforcing effect of restorative materials in simulated immature teeth.[9]

The open apex in immature teeth throws a challenge to the clinician. There are various treatment modalities mentioned in the literature regarding open apex in immature teeth namely apexification, apexogenesis, revascularization, and regeneration.[13-15] In all the above-mentioned modalities, there exists a certain drawback regarding the lengthy time frame, which may pose a threat to the weakened root dentine in

Table 1: Comparison of mean peak load required to cause cervical fracture between the experimental groups and control group(Newtons)

Group	Number of sample	Load at fracture (N) Mean±SD	*t*	*P* (significant)
FRC	20	1199.70±174.99	23.558	0.001(HS)
Control	20	236.70±52.91		
Bio-dentine	20	609.75±72.94	18.514	0.001(HS)
Control	20	236.70±52.91		
Modified GIC	20	512.00±70.73	13.938	0.001(HS)
Control	20	236.70±52.91		

GIC: Glass ionomer cement, HS: High significant, SD: Standard deviation, FRC: Fiber reinforced composite the immature teeth particularly in the cervical area. In case of a consecutive injury, the immature teeth will be more susceptible to fractures that can affect their restorability status.

Considering the drawbacks of apexification, apexogenesis, regenerative procedures and revascularization in Cvek's Stage III of root development there is growing popularity with single visit apical barrier placement.[16-18] Currently, various biomimetic materials have been used for apical barrier placement procedures.[17]

Biodentine is a calcium silicate-based product and was introduced in 2009. It was chosen over MTA as an apical barrier placement material taking into consideration few concerns regarding MTA such as extended setting time, handling characteristics, low compressive strength and resistance to flow. The setting time of Biodentine is 9–12 min, and it does not require two-step obturation, and the treatment can be completed in a single appointment.[19]

The thermoplastic gutta-percha was filled in between the apical barrier and experimental materials for the assessment of canal to deal with any future complications simulating clinical conditions. Gutta-percha gives the easy accessibility for re-treatment.[13]

FRC was first described in 1960 by Smith. This type of composite material is very heterogeneous, considering the nature of the fiber and the overlying resin.[20] FRC has randomly oriented short glass fiber as filler content in the composite. It exhibits insignificant polymerization shrinkage stresses and amplifies the stress-relieving capacity of the matrix, thereby decreasing microleakage and improving the adaptation of the material.[21,22]

It demonstrates superior compressive strength and acts as dentine replacing material.[22] FRC exhibited the highest fracture resistance value of 1199.70 N among all experimental groups. This material could prove to be a promising material in reinforcing the cervical third of the immature teeth.

Biodentine exhibits adequate compressive strength to resist the masticatory load similar to that of dentine. It has the capacity to improve its compressive strength with time until it matches the strength of natural dentine. Biodentine has the finer particle size thus reducing the porosity and therefore imparts better sealing and adaptation to dentine.[23,24] It exhibited a fracture resistance of 609.75 N, which is significantly lower than FRC but significantly higher than that of Bioglass R.

The third experimental material was Bioglass R. It consists of inorganic fillers as a powder and polyacrylic acid, tartaric acid, and deionized water as a liquid. GICs exhibit superior chemical adhesion to tooth structure and base metals. However, it lacks superior mechanical strength and toughness.[25]

The low fracture resistance of Bioglass R can be attributed to mechanisms such as void nucleation, crack propagation, and detachment of particles or sudden, subcritical failure.[25,26] Bioglass R showed significantly lower fracture resistance compared with FRC and Biodentine.

In several studies done earlier, an angle of approximately 45° to 130° has been used considering the values of mechanics where in the forces acting at an angle may be resolved into horizontal and vertical components. A load to fracture was delivered at an angle of 130°, simulating the normal angle of contact between maxillary and mandibular incisors.[27]

The cyclic loading of the teeth makes it difficult to accurately record the amount of compressive load exerted on healthy teeth. According to Anusavice, the average maximum sustaining force is approximately 756 N (133 Mpa).[28]

Research by Anderson[29] has demonstrated that ordinary chewing forces in adult ranges from 7 (68.64 N) to 15 kg (147 N). When comparing the mean fracture load values of all the samples in this study, the values were in clinically acceptable range. Thus, it is assumed that the experimental materials evaluated in this study met the requirement of the strength required to resist routine physiological forces in oral cavity.

CONCLUSION

The study was an *in vitro* study; hence, results could vary in virtual *in vivo* oral conditions. The null hypothesis was proven wrong since there was a statistical difference in the reinforcing capacity of the experimental materials. Hence, it can be concluded that the placement of FRC appreciably improved the fracture resistance of the weakened simulated immature teeth followed by Biodentine and Bioglass R.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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