

Comparative evaluation of fracture resistance of simulated immature teeth and its effect on single visit apexification versus complete obturation using MTA and biodentine

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ABSTRACT

Aim and Objectives: This study sought to evaluate and compare the fractured resistance of simulated immature teeth and the effect of single visit apexification versus complete obturation using MTA and biodentine. **Material and Methodology:** Forty-five freshly extracted sound maxillary central incisors with single canal were selected. The apical 5 mm of each sample was then sectioned to simulate Cvek's stage 3 root development access cavity preparation, followed by preparation using peeso reamers. Irrigation was carried out followed by randomization of samples. Obturation was performed using different materials. Fracture resistance was checked under universal testing machine, by recording the ultimate load to fracture in Newtons. **Statistical Analysis:** Statistical analysis was performed using SPSS 20.0 Software. One-way analysis of variance followed by pair wise comparison of the groups was performed using Tukey's post-hoc test. The significance level was set at $P < 0.05$. **Results:** All the experimental groups showed statistically higher value of fracture resistance than the control groups. Group I (entire canal obturated with MTA) reported highest value of fracture resistance followed by group III (entire canal obturated with biodentine), group II, and group IV. **Conclusion:** In apexification cases, reinforcing the immature teeth with bioceramic materials such as MTA and biodentine is advantageous. **Clinical Significance:** Clinically in patients, high success rate of apexification can be achieved with complete MTA obturation as compared to MTA and biodentine apical plug and gutta percha obturation.

Keywords: Apexification, biodentine, MTA, obturation

Introduction

Trauma to the anterior teeth is the most frequent cause for pulpal necrosis and cessation of root development. Because of open apices and weak dentinal walls, the management of such cases is

both an endodontic and restorative challenge which predispose such teeth to root fractures at the cervical dentin.^[1] Apexification is one of the best treatment modality in such cases.

Apexification with long-term calcium hydroxide is reported to have a success rate of 79–96%. However, the unpredictable time for apical barrier formation, increased brittleness of the tooth,

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and susceptibility to root fractures are its major disadvantages.^[2,3] To surmount these disadvantages, various bioceramic materials with superior properties such as osteogenic potential, sealing ability, and antibacterial property have been used for single visit apexification.^[4,5] MTA is considered to be the gold standard material as an artificial apical barrier inducer in immature and incompletely developed teeth.^[6,7] Various studies have reported that complete obturation of immature teeth with MTA can enhance their resistance to horizontal as well as vertical root fractures.^[8,9] Biodentine is a dentin substitute and a relatively new bioceramic cement with similar mechanical and physical properties as MTA but with better handling characteristics can serve as suitable alternative to MTA.^[10-12] Although it is established that apexification can result in the formation of hard tissue apical barrier, but the thin dentinal walls at the cemento-enamel junction may leave the teeth prone to cervical fractures from secondary injuries like mastication or trauma, thus leaving them unrestorable.^[13-15] The percentage of such cases has been shown to be in the range of 28–77%.^[16] Thence, reinforcing the roots by using MTA/biodentine as an obturating material could be salutary.

As there is paucity in literature on effect of bioceramic materials and its effect on fracture resistance of immature teeth when used as an obturating material, the present study is framed to evaluate the fracture resistance and the pattern of fracture (favorable/unfavorable) of simulated immature teeth filled with either a 5 mm apical plug or a complete obturation of MTA/biodentine.

Material and Methodology

Forty-five freshly extracted sound maxillary central incisors with single canal were collected from Department of Oral and maxillofacial surgery and kept in normal saline. Intraoral periapical radiographs were taken with different angulation and teeth with calcified canals, resorptive defects, or an additional canal were excluded from the study. All teeth were examined under magnification for cracks and fractures, before and after instrumentation. Teeth with similar dimensions were selected, the faciolingual and mesiodistal root diameters were measured below the cemento-enamel junction using Boley's gauge. Samples with a length of 20 ± 0.5 mm were selected and stored in saline until use, for standardization. The apical 5 mm of each sample was sectioned using a low-speed diamond saw. Access cavity was prepared using a round bur and the pulp was extirpated. The canals were then prepared with peeso reamers (size 1–5) until no. 5 peeso reamer could easily pass 1 mm beyond the apex to simulate an immature tooth. To simulate Cvek's stage 3 of root development, a no. 6 peeso reamer was used to prepare the canal 3 mm below the cemento-enamel junction such that canal wall thickness of 1.5 mm was obtained. Irrigation was performed using 2.5% sodium hypochlorite during instrumentation. Final irrigation was done with 5 ml of 2.5% sodium hypochlorite, 3 ml of 17% EDTA, and 5 ml normal saline as a final rinse.

Using a randomized stratified design, the samples were divided into four experimental ($n = 10$) and 1 control group ($n = 5$) as follows:

- Group 1 ($n = 10$):- Complete canal obturation with MTA
- Group 2 ($n = 10$):- 5 mm apical plug of MTA, rest of the canal was obturated with gutta percha and AH Plus sealer
- Group 3 ($n = 10$):- Complete canal obturation with biodentine
- Group 4 ($n = 10$):- 5 mm apical plug of biodentine, rest of the canal was obturated with gutta percha and AH Plus sealer
- Control Group ($n = 5$):- The entire canal was obturated with gutta percha and AH Plus sealer using cold lateral compaction.

The quality assessment of obturation and the apical plug was confirmed with radiographs, after which post-obturation restoration was done by composite resin. The samples were stored at 37°C and 100% humidity for 1 week.

PDL simulation and fracture testing

PDL simulation was done by covering the roots with elastomeric impression material. To simulate physiologic relationship between the tooth and the bone crest, the roots were embedded in autopolymerizing resin blocks such that there was a 2 mm gap between the cemento-enamel junction and top of the resin. Fracture testing was performed under universal testing machine and load was applied with a 5 mm chisel shaped indenter at 130° to the long axis of the tooth at a point 3 mm above the cemento-enamel junction in a lingual direction at a crosshead speed of 1 mm/min until the fracture occurred. The ultimate load to fracture was recorded in Newtons.

The pattern of fracture was also evaluated using the following criteria:

- a) Favorable or b) Unfavorable fractures.

Statistical analysis

The data was analyzed using SPSS 20.0 Software for statistical analysis. One-way analysis of variance revealed significant difference among the groups. Pair wise comparison of the groups was performed using Tukey's post-hoc test. The level of significance was set at $P < 0.05$.

Results

The mean value of fracture resistance and standard deviation for all experimental groups is shown in Table 1. The mean value of fracture resistance was recorded in the following order: Group 1 (Full MTA Obturation) > Group 3 (Full Biodentine Obturation) > Group 2 (5 mm MTA Apical Plug) > Group 4 (5 mm Biodentine Apical plug) > Control Group (Gutta percha + AH Plus Obturation). Graphical representation of mean value of fracture resistance as Graph 1.

Tukey post-hoc test for multiple group comparison was applied and results are as shown in Table 2. Group 1 showed higher

fracture resistance than group 3 but there was no statistically significant difference reported ($P > 0.05$). Group 1 and Group 3 performed significantly better as compared to Group 2 and Group 4 ($P < 0.05$). No statistical significant difference was reported between Group 2 and Group 4.

With regard to the fracture pattern, in all the experimental groups only horizontal fracture at the level of cemento-enamel junction or oblique fractures extending up to the cervical third were observed without any statistical significant difference between them. The samples in control group showed unfavorable fractures extending beyond the middle third root level.

Discussion

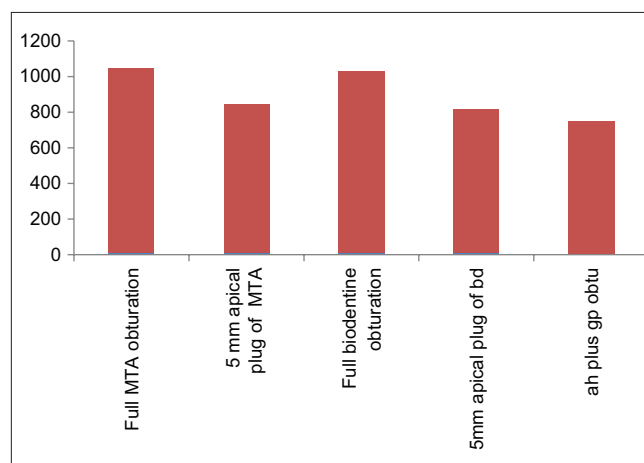
Apexification has been the well established treatment modality with high success rate, but still the tooth structure remains prone to fracture due to the thin dentinal walls. The tissue loss of the tooth reduces the fracture resistance toward traumatic forces. Thus, reinforcement of fragile radicular dentin in immature teeth is of utmost importance.^[9,11]

Table 1: Mean fracture resistance and standard deviation of all experimental groups

| | n | Mean | Std. Deviation | Minimum | Maximum | P |
|-----------------|----|-----------|----------------|---------|---------|-------|
| Full MTA | 10 | 1034.1250 | 65.74363 | 928.74 | 1124.24 | |
| 5 MM MTA | 10 | 831.6270 | 152.34314 | 454.83 | 988.75 | 0.000 |
| Full Biodentine | 10 | 1018.3610 | 48.55024 | 928.67 | 1065.96 | |
| 5 MM Biodentine | 10 | 806.5320 | 119.71707 | 533.93 | 976.89 | |
| Control Group | 5 | 741.9612 | 80.41450 | 654.70 | 864.24 | |
| Total | 45 | 902.5835 | 150.94598 | 454.83 | 1124.24 | |

MTA is considered gold standard as an apical barrier in immature teeth when compared to calcium hydroxide.^[13] However, studies have shown controversial results regarding the ability of MTA to strengthen tooth structure when used as an obturation material. White *et al.* reported weakening of tooth structure after 5 weeks of exposure to MTA by 33%. It was concluded that breakdown of the protein structure by the alkalinity of MTA was responsible for this result.^[14] Andreasen *et al.* reported that fracture resistance of teeth treated with MTA was higher than those filled with either saline or calcium hydroxide.^[15]

Biodentine is bioceramic material advertised as “bioactive dentine substitute,” it claims to possess improved physical, mechanical, and handling properties as compared to MTA. Han and Okiji concluded from their study that biodentine may have remarkable biomineralization capacity as compared to MTA.^[17]



Graph 1: Graphical representation of mean value of fracture resistance

Table 2: Tukey post hoc test for multiple group comparison

| | | Mean Difference (I-J) | Std. Error | P SIG. |
|---------------------------------|---------------------------|-----------------------|------------|--------|
| Full MTA Obturation | 5 mm Apical MTA Plug | 202.49800* | 46.03508 | 0.001 |
| | Full Biodentine (BD) Obt. | 15.76400 | 46.03508 | 0.997 |
| | 5mm Apical Plug of BD | 227.59300* | 46.03508 | 0.000 |
| | A.H. Plus Grp Obt | 292.16380* | 56.38122 | 0.000 |
| 5 mm MTA Apical Plug | Full MTA Obturation | -202.49800* | 46.03508 | 0.001 |
| | Full Biodentine (BD) Obt. | -186.73400* | 46.03508 | 0.002 |
| | 5mm Apical Plug of BD | 25.09500 | 46.03508 | 0.982 |
| | A.H. Plus Grp Obt. | 89.66580 | 56.38122 | 0.512 |
| Full Biodentine (BD) Obturation | Full MTA Obturation | -15.76400 | 46.03508 | 0.997 |
| | 5 mm MTA Apical Plug | 186.73400* | 46.03508 | 0.002 |
| | 5mm Apical Plug of BD | 211.82900* | 46.03508 | 0.000 |
| | A.h. Plus Grp Obt. | 276.39980* | 56.38122 | 0.000 |
| 5mm Apical Plug of BD | Full MTA Obturation | -227.59300* | 46.03508 | 0.000 |
| | 5 mm Apical MTA Plug | -25.09500 | 46.03508 | 0.982 |
| | Full Biodentine (BD) Obt. | -211.82900* | 46.03508 | 0.000 |
| | A.H. Plus Grp Obt. | 64.57080 | 56.38122 | 0.782 |
| A.H. Plus Group Obt. | Full MTA Obturation | -292.16380* | 56.38122 | 0.000 |
| | Full Biodentine (BD) Obt. | -89.66580 | 56.38122 | 0.512 |
| | 5mm Apical MTA Plug | -276.39980* | 56.38122 | 0.000 |
| | 5mm Apical Plug of BD | -64.57080 | 56.38122 | 0.782 |

Very few studies have evaluated and compared the reinforcement of the cervical dentinal walls in immature teeth when complete obturation or an apical plug is given with these bioceramic materials.

In the present study, maxillary central incisors were selected as they are more prone to trauma and external impact owing to their location.^[18,19] Cvek's stage 3 of root development was simulated as this stage provides an experimental tooth model with root to canal ratio of 1:1 in the mesiodistal dimension at the CEJ.^[4,5] To approximate the clinical scenario, the teeth were embedded in acrylic resin for homogenous stress distribution and PDL stimulation was done with elastomeric impression material.^[11] Fracture resistance was performed under universal testing machine at a crosshead speed of 1 mm/min. The load was applied at an angle of 130° to the long axis of the tooth as it mimics the average angle of contact between the maxillary and the mandibular incisors in Class I occlusion.^[20,21]

In the current study it was reported that all experimental groups had a statistically higher value of fracture resistance than the control groups, indicating that the tested experimental groups considerably enhanced the fracture resistance of immature teeth. Group I (entire canal obturated with MTA) showed highest value of fracture resistance followed by group III (entire canal obturated with biodentine), group II, and group IV.

Because of their bioactive nature, that is, their ability to form hydroxyapatite layer between the dentine and the material, the reinforcing effect of complete MTA and complete biodentine group were better.^[22] Our results are in agreement with the study by Milani *et al.* who demonstrated that similar modulus of elasticity of MTA and dentin could be the best probable reason for the reinforcing effect of MTA. The elastic modulus of MTA is in the range of 15–30 GPa and of biodentine is around 22 GPa approximating that of dentin which is about 14–18.6 GPa.^[20] A FEM analysis showed that a material with modulus of elasticity similar to that of dentin can reinforce the weakened root.

Inability of gutta percha to reinforce the weakened root in the cervical area could be the reason for the lower fracture resistance of apical plug groups, which is due to its poor cohesive strength and lower elastic modulus.^[7] This was further confirmed by the fracture pattern seen in these groups, that is, oblique fracture, extending till the middle third of the root, thus leaving them unrestorable.

The mean value of fracture resistance for group I was higher than group III, but the difference was not statistically significant. This finding is in accordance with the results of a study by Elnaghy and Elaska *et al.*^[11] The most probable reason for better performance of complete MTA obturation could be attributed to the hypothesis proposed by Hatibovic-Kofman that tissue inhibitor of MMP was expressed in the MTA treated teeth.^[19,20] Bogen G *et al.* also demonstrated that MTA can release bioactive molecules that have been sequestered in the dentin matrix. It

was thought that the change in the dentin matrix as a result of biological interaction between MTA and dentin may inhibit destruction of organic matrix of dentin.^[21,23-25]

The limitations of this current study include use of simulated immature teeth and the results could vary in actual clinical scenario. In addition, the load was applied at a crosshead speed of 1 mm/min, so future studies with higher velocities of 500 mm/min that more accurately reflects the forces that cause trauma, needs to be carried out. Moreover, long-term clinical trials are also needed to best evaluate the performance of biodentine and MTA as obturating materials in immature teeth.

Conclusion

In accordance with the obtained results it can be concluded that reinforcing immature teeth with bioactive materials such as MTA and biodentine is advantageous. Neither of the two tested materials, that is, biodentine or MTA offer an edge over the other in terms of enhancing the fracture resistance of immature teeth. Thus, biodentine can be recommended as obturating material over MTA due to its short setting time and favorable handling characteristics. Trauma to anterior teeth results in open apex and necrosis. Anterior teeth are most concerned teeth due to aesthetics and the management of such cases is both an endodontic and restorative challenge, hence primary care is most vital in treating such cases.

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Conflicts of interest

There is no conflicts of interest.

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