Original Article

Effect of Single Visit Apexification versus Complete Obturation using Mineral Trioxide Aggregate or Biodentine on the Fracture Resistance of Simulated Immature Teeth

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ABSTRACT

Introduction: The study was done to evaluate and compare the effect of single visit apexification or full obturation of mineral trioxide aggregate (MTA)/ Biodentine on fracture resistance and pattern of fracture of simulated immature teeth.

Methodology: Forty-five extracted maxillary central incisors were decoronated to a standard length of 20 mm and were divided into four experimental groups (n=10) and one control group (n=5). Peeso reamers (#1 to #5) were used to simulate immature teeth until they passed 1mm beyond the apex. Peeso reamer #6 was used 3mm beyond the cemento-enamel junction (CEJ) to mimic Cvek's stage 3 of root development. Canals in group 1 and 3 were completely obturated using MTA and Biodentine, respectively. Apexification with 5mm MTA and biodentine was done in group 2 and 4 and backfilled with guttapercha and AH Plus sealer, respectively. Fracture testing was performed using Universal Testing Machine and data was subjected to statistical analysis.

Results: Complete obturation with MTA and Biodentine showed significantly higher fracture resistance than MTA and biodentine apexification groups.

Conclusion: Full obturation with bioactive materials reinforces simulated immature teeth.

INTRODUCTION

Trauma to the anterior dentition during young age is the most common cause for pulpal necrosis and cessation of root development. The management of such cases is both an endodontic and restorative challenge because of open apices and weak dentinal walls which predispose such teeth to root fractures at the cervical dentine.[1]

The ideal treatment strategy recommended is regenerative endodontic protocol as it promotes hard tissue formation and leads to continued root development. But in cases where regenerative procedure is not an indication or possibility, alternative treatment approaches such as apexification should be considered.[2] Apexification with long term calcium hydroxide is known to have a success rate of 79-96%. However, the unpredictable time for apical barrier formation, increased brittleness of the tooth, and susceptibility to root fractures are its major disadvantages.[3,4] To overcome these disadvantages, various bioactive materials with superior properties such as enhanced sealing ability, antibacterial, and osteogenic potential have been advocated for single visit apexification.[5] Mineral trioxide aggregate (MTA) has been quite popular as an artificial apical barrier inducer in immature and incompletely developed teeth.[6] Researchers have advocated that complete obturation of immature teeth with MTA can enhance their resistance to horizontal as well as vertical root fractures.[7,8] Biodentine, a dentine substitute and a relatively new bioactive cement with similar mechanical and physical properties as mineral trioxide aggregate but with better handling characteristics can serve to be a suitable alternative to MTA. 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.[9] The percentage of such cases has been shown to be in the range of 28-77%.[10] Therefore, it could be advantageous to reinforce the roots by using MTA/biodentine as an obturating material.

As there is scarcity of literature on effect of bioactive materials on fracture resistance of immature teeth when used as an obturating material, the aim of present study was to evaluate the fracture resistance and the pattern of fracture (favourable/unfavourable) of simulated immature teeth filled with either a 5mm apical plug or a complete obturation of MTA/biodentine.

METHODS

An experimental comparative study was performed. For this study, forty-five freshly extracted non-carious maxillary central incisors with single canal were selected. Periapical radiographs were taken with two different angulations and teeth with calcified canals, resorptive defects or an additional canal were excluded. All teeth were examined under magnification for cracks and fractures, before and after instrumentation. The facio-lingual and mesio-distal root diameters were measured below the cement-enamel junction using Boley's gauge and teeth with similar dimensions were selected.

For standardization, samples with a length of 20 ±0.5mm were selected and stored in saline until use. The apical 5mm of each tooth was then removed using a low-speed diamond saw. Coronal access cavity was prepared with a size 4 round bur and the pulp was extirpated using a barbed broach. Next, the canals were prepared with peeso reamers (size #1-5) until size number 5 peeso reamer could easily pass 1 mm beyond the apex to simulate an immature tooth. A number 6 peeso reamer was then used to prepare the canal 3mm below the cemento-enamel junction such that canal wall thickness of 1.5 mm was obtained to simulate Cvek's stage 3 of root development. 2.5% sodium hypochlorite was used as an irrigant during instrumentation. Final irrigation was performed with 5 ml of 2.5% sodium hypochlorite followed by 5ml of 17% EDTA and 5 ml normal saline was used as a final rinse.

The samples were then divided into 4 experimental (n=10) and 1 control group (n=5) as follows using a randomized stratified design:-

- Group 1 (n=10): The entire canal was obturated with MTA.
- Group 2 (n=10): 5 mm apical plug of MTA was formed and rest of the canal was obturated with guttapercha and AH Plus sealer.
- Group 3 (n=10): The entire canal was obturated with Biodentine.
- Group 4 (n=10): 5 mm apical plug of Biodentine was formed and rest of the canal was obturated with guttapercha and AH Plus sealer.
- Control Group (n=5): The entire canal was obturated with guttapercha and AH Plus sealer using cold lateral compaction.

The quality of obturation and the apical plug was confirmed with radiographs, after which the access cavities were sealed with composite resin. The specimens were stored at 37° C and 100% humidity for one week.[1]

Figure 1: Coronal access cavity preparation.

Figure 2: Simulation of open apex.

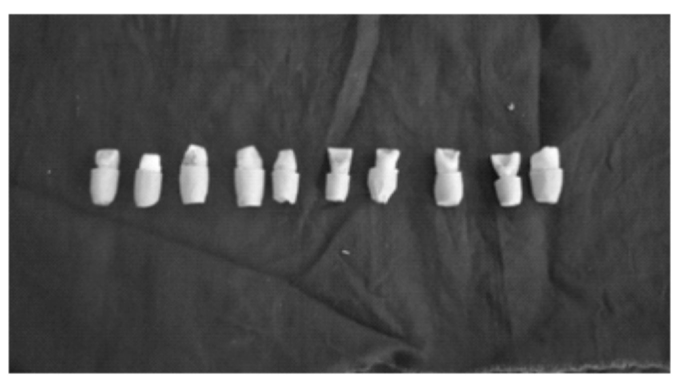

Figure 3: Root surface covered with polyvinylsiloxane impression material to simulate periodontal ligament.

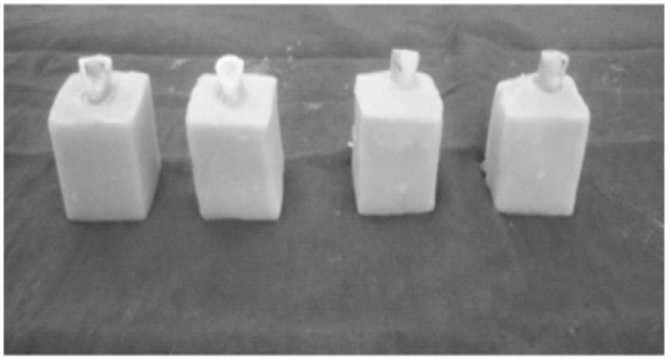

Figure 4: Roots embedded in 1x1 cm acrylic blocks.

PDL simulation was done by covering the specimen roots with polyvinylsiloxane impression material. The roots were embedded in autopolymerising resin blocks such that there was a 2mm gap between the cemento-enamel junction and top of the resin to simulate physiologic relationship between the tooth and the bone crest.

Fracture testing was done using universal testing machine and load was applied with a 5mm chisel shaped indentor at 130° to the long axis of the tooth at a point 3mm above the cemento-enamel junction in a lingual direction at a crosshead speed of 1mm/min until the fracture occurred. The ultimate load to fracture was recorded in Newtons.

Fracture pattern Analysis

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

(a) Favourable (b) Unfavourable fracture

Statistical Analysis

The obtained data was subjected to statistical analysis using SPSS 20.0 software. One way analysis of variance was used to analyse 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 95% ($p < 0.05$).

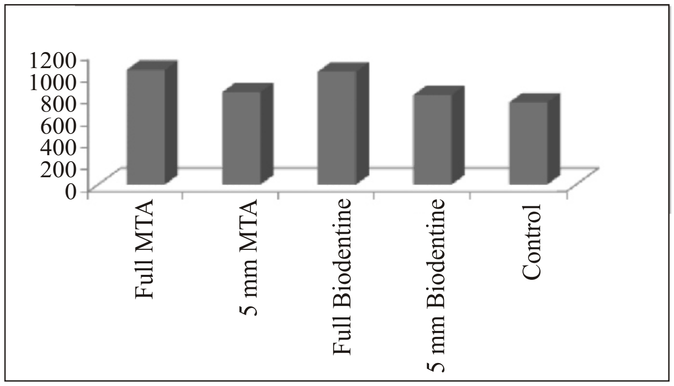

Figure 5: Graphical representation of mean value of fracture resistance.

RESULTS

The mean value of fracture resistance and standard deviation for all experimental groups is shown in table 1. Figure 5 depicts a graphical representation of the mean value of fracture resistance of the experimental group. The mean value of fracture resistance was recorded in the following order:

Group 1 (Full MTA Obturation) > Group 3 (Full Biodentine Obturation) > Group 2 (5mm MTA Apical Plug) > Group 4 (5 mm Biodentine Apical Plug) > Control Group (Guttapercha + AH Plus Obturation).

Table 2 shows results of post-hocTukey's analysis for multiple group comparison.

According to post-hoc tests, group 1 showed higher fracture resistance than group 3 but the difference was not statistically significant (p value >0.05). Group 1 and group 3 performed significantly better than group 2 and group 4, p value < 0.05. No significant difference was found between group 2 and group 4.

The pattern of the fracture was evaluated according to the position of the fracture.

Table 1: Mean fracture resistance of all experimental groups

	N	Mean ± S. D.	Minimum	Maximum	p-value
Full MTA	10	1034.12 ± 65.74	928.74	1124.24	0.000
5 mm MTA	10	831.63 ± 152.34	454.83	988.75	
Full Biodentine	10	1018.36 ± 48.55	928.67	1065.96	
5 mm Biodentine	10	806.53 ±119.71	533.93	976.89	
Control	5	741.96 ± 80.41	654.70	864.24	
Total	45	902.58 ± 150.94	454.83	1124.24	

$p < 0.05$, significant

Table 2: Tukey post hoc test for multiple group comparison

		Mean Difference (I-J)	S.E.	p-Value
Full MTA Obturation	5 mm Apical MTA lug	202.49800*	46.03508	0.001
	Full BD Obturation.	15.76400	46.03508	0.997
	5mm Apical Plug of BD	227.59300*	46.03508	0.000
	AH + Group Obturation	292.16380*	56.38122	0.000
5 mm MTA Apical Plug	Full MTA Obturation	-202.49800*	46.03508	0.001
	Full BD Obturation	-186.73400*	46.03508	0.002
	5mm Apical Plug of BD	25.09500	46.03508	0.982
	AH + Group Obturation	89.66580	56.38122	0.512
Full Biodentine 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
	AH + Group Obturation	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 BD Obturation	-211.82900*	46.03508	0.000
	AH + Group Obturation	64.57080	56.38122	0.782
AH Plus Group Obturation	Full MTA Obturation	-292.16380*	56.38122	0.000
	Full BD Obturation	-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

BD : Biodentine; MTA : Mineral Trioxide Aggregate

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

DISCUSSION

The high success rate of apexification has been well established, 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 towards traumatic forces. Thus, reinforcement of fragile radicular dentine in immature teeth is of utmost importance.[7,9,11]

MTA has shown promising results as an apical barrier in immature teeth when compared to calcium hydroxide.[12] However, studies regarding the ability of MTA to strengthen tooth structure when used as an obturation material has shown controversial results. White et al[13] showed weakening of tooth structure after 5 weeks of exposure to MTA by 33%. They hypothesized that breakdown of the protein structure by the alkalinity of MTA was responsible for this result. Andreasen et al[14] reported that fracture resistance of teeth treated with MTA was higher than those filled with calcium hydroxide.

Biodentine is a newer active biosilicate technology based cement known to have improved physical, mechanical, and handling properties as compared to MTA. Han and Okiji[15] reported that biodentine may have remarkable bio mineralization capacity than MTA. Literature review indicates that Biodentine apexification can improve the fracture resistance of simulated immature teeth.

To our knowledge, very few studies have compared the reinforcement of the cervical dentinal walls in immature teeth when full obturation or an apical plug is given with these bioactive materials. In the present study, maxillary central incisors were selected as they are more susceptible to trauma and external impact owing to their location.[16,17] 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 mesio-distal dimension at the CEJ.[7,8] The teeth were embedded in acrylic resin for homogenous stress distribution and PDL simulation was done with polyvinyl siloxane impression material to approximate the clinical scenario.[9] Fracture testing was performed using universal testing machine at a crosshead speed of 1mm/min. The load was applied at an angle of 130 degree to the long axis of the tooth which mimics the average angle of contact between the maxillary and the mandibular incisors in class I occlusion.[18,19]

The results of the present study indicate 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 least fracture resistance was noted in group IV.

The reinforcing effect of full MTA and full biodentine groups may be better because of their bioactive nature i.e. their ability to form hydroxyapatite layer between the dentine and the material.[15,20] Our results are in agreement with the study by Milani et al[21] who demonstrated that the reinforcing effect of MTA could be due to the similar modulus of elasticity of MTA and dentine. The elastic modulus of MTA is in the range of 15-30 GPa and of biodentine is around 22 GPa approximating that of dentine which is about 14-18.6 GPa. A FEM analysis showed that a material with modulus of elasticity similar to that of dentine can reinforce the weakened root.[22]

The lower fracture resistance of apical plug groups could be because of the inability of guttapercha to reinforce the weakened root in the cervical area, due to its poor cohesive strength and lower elastic modulus.[23] This was further confirmed by the fracture pattern seen in these groups, i.e. 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.[1] The most probable reason for better performance of full MTA obturation could be attributed to the hypothesis that tissue inhibitor of MMP was expressed in the MTA treated teeth.[24] Bogen et al[25] also demonstrated that MTA can release bioactive molecules that have been sequestrated in the dentine matrix. They also postulated that the change in the dentine matrix was a result of biological interaction between MTA and dentine which might have been responsible for inhibition of destruction of organic matrix of dentine.

The limitations of the study include use of simulated immature teeth and the results could vary in actual clinical scenario. Also, the load was applied at a crosshead speed of 1mm/min, so future studies with higher velocities of 500 mm/min that more accurately reflects the forces that cause trauma, need to be carried out.[26] Furthermore, long term clinical trials are also needed to best evaluate the performance of biodentine and MTA as an obturating material in immature teeth.

CONCLUSION

Reinforcing immature teeth with bioactive materials such as MTA and biodentine is advantageous. Neither of the two tested materials i.e. 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 an obturating material over MTA due to its short setting time and favorable handling characteristics.

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