Efficacy of Mineral Trioxide Aggregate as an Apical Plug in Non-Vital Young Permanent Teeth: Preliminary Results

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Purpose: *The purpose of this study was to evaluate the efficacy of Mineral trioxide aggregate (MTA) clinically and radiographically as material used to induce root end closure in nonvital permanent teeth with immature apices (apexification) in children.* ***Methods:*** *The study included 30 non vital young permanent, single rooted teeth of 22 children between 8 and 13 years of age. Treatment followed a standard non-surgical root canal treatment protocol and the root canal was filled with a apical plug of 4-5 mm of MTA (white MTA – Angelus, Brazil), followed by gutta-percha obturation. The children were reviewed for 1 year at 3 month interval and the teeth were assessed clinically and radiographically.* ***Results:*** *MTA showed success rate of 100% both clinically and radiographically at the 12th months follow up and root end closure was seen in 86.6% of cases and root growth in 30% of cases.* ***Conclusions:*** *MTA showed clinical and radiographic success as an apexification material by inducing root end closure and root growth in non-vital young permanent teeth.*

Keywords: *Apexification, Mineral trioxide aggregate (MTA), non-vital young permanent teeth, apical plug, open apex.*

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INTRODUCTION

The success of endodontic treatment of a nonvital tooth depends on elimination of infection by proper cleaning and shaping, followed by hermetic seal of the root canal system. Endodontic management of non-vital immature teeth with open apex is challenging because of the presence of large divergent canals, thin and fragile walls, lack of apical stop and difficulty in obtaining an optimal seal of the root canal system.

The treatment options for such an open apex tooth varied widely starting from no treatment to a method to induce root end closure. Root-end closure, also known as apexification, is defined as the process of creating an environment within the root canal and periapical tissues after pulp death that allows a calcific barrier to form across the open apex. This barrier has been characterized as dentin, cementum, bone, and osteodentin. The result is blunting of the root end and very little, if any increase in root length.[1] Numerous materials have been recommended to induce root end closure in teeth with immature apices which include no treatment,[2] infection control,[3] induction of blood clot in the periradicular tissue,[4] antibiotic pastes,[5] calcium hydroxide,[6] tricalcium phosphate,[7] Ca-Glycerophosphate,[8] MTA[9] and bone regenerative materials like oxidised regenerated cellulose,[10] demineralized dentin, hydroxyapatite, dentin chips,[11] bone growth factors – osteogenic protein-1,[12] freeze dried allogenic dentin powder and true bone ceramic.[13]

Calcium hydroxide has become the material of choice for apexification, it is bactericidal with an alkaline pH that may be responsible for stimulating apical calcification.[14] Despite its popularity for the apexification procedure, it has some inherent disadvantages, including variability of treatment time(3-54 months), unpredictability of apical closure, difficulty in patient follow-up, and delayed treatment.[12,15,16] Calcium hydroxide may also further weaken the teeth by the repetition of endodontic procedures during the replacement of the intracanal dressing[17] and the prognosis may be compromised by the placement of a temporary coronal seal. Also, it has some tissue altering and dissolving effects.[18] Therefore the search continues for procedures and materials that may allow more natural continued apical closure in teeth with immature apices.

A new material MTA has been developed by Torabinejad in 1993 which has been used in endodontics that appears to be a significant improvement over other materials with

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impressive physical and chemical properties,[19] and a high degree of biocompatibility.[20,21,22]

MTA has several advantages over calcium hydroxide as an apexification medicament like short treatment period which can be finished in 1-3 visits,[23,24,25] with a setting time of 2 hours and 47 minutes and high compressive strength[19] thus eliminating the 3 to 54 month waiting time required for calcium hydroxide apexification.[15,16,,26] It has the capacity to induce root end closure.[23] Although numerous articles have been published regarding the use of MTA as a root-end filling material, majority of them were case reports and animal studies, and there is a little published information about its use in cases of non-vital young permanent teeth in humans especially in children. Thus this study was undertaken to evaluate the clinical efficacy of Mineral Trioxide Aggregate (MTA) as an apexification medicament in non-vital young permanent teeth in children.

MATERIALS AND METHOD

The study was conducted on 30 non vital young permanent, single rooted teeth of 22 children ranging from 8 to13 years old (26 were maxillary central incisors, 2 maxillary lateral incisors, 1 mandibular lateral incisor and 1 mandibular premolar) who attended the out patient department of Pediatric & Preventive dentistry, Ragas Dental College & Hospital, Chennai. Participation in the study was voluntary and a written informed consent was obtained from the parents or guardians. The study was approved by the Institutional Review Board (IRB) of Ragas Dental College and Hospital.

Histological Evaluation

One tooth other than the study sample, treated for perforation repair as well as for open apex with MTA was fractured after 9 months because of repeated trauma and the remaining root fragment was extracted and evaluated histologically. This was not included in the study sample because it could not be followed for the entire study period.

Sample selection for apexification was done following the criteria recommended by Walton and Torabinejad (2002),[1] which includes

1. immature teeth with pulp necrosis
2. teeth must be ultimately restorable
3. no vertical or horizontal root fractures
4. no radiographic evidence of replacement resorption (ankylosis)
5. root length must be approximately half or more established (Moorrees[27] stage 3-5) and
6. teeth selected only in subjects free from any systemic diseases.

To familiarize the operator with material handling properties and the MTA placement technique, extracted human incisors were prepared to resemble immature teeth with an open apex; the procedure was practiced and familiarized on these teeth.[28]

Treatment followed a standard non-surgical root canal treatment protocol. Clinically, the stage of root development was assessed during the root canal preparation. Teeth suitable for MTA apexification, i.e. with open apices, were identified after the insertion of a large endodontic file (size 60)[28] beyond the working length without any resistance at the apical portion. Working length of the root canal was then determined radiographically and instrumentation was performed with a gentle circumferential filing motion using endodontic files 2mm short of the radiographic apex to avoid over instrumentation of the fragile dentinal wall near the open apex and to prevent injury to the periapical tissues. Copious irrigation with 0.2% chlorhexidine solution and saline was done alternatively to remove the necrotic debris. Final irrigation was done with normal saline and the canal was dried with large (wide) paper points. If periapical infection persisted, the patients were recalled and the procedure was repeated till the infection subsided. MTA (white MTA – Angelus, Brazil) was mixed according to manufacturer's instruction and placed in the canals using MTA endo carrier (Dentsply) and condensed using endodontic plugger to the apical end of the root to create 4-5mm[29] apical plug. The correct placement, extension and quality of fill of the MTA was assessed with the help of radiographs,[28] so that the MTA apical plug corresponded to the radiographic apex and did not over-extend into the periapical area or appear to underfill the apical 3 mm of the root and there was no space between the material and the walls of the canal. If found inadequate, the root canal was re-accessed and the material was washed out by thorough irrigation and instrumentation in order to be replaced. A moist cotton pellet using sterile water was placed over the material followed by a dry cotton pellet[28,30,31,32] and the access cavity was sealed with IRM.[32] In the next appointment, the set of the MTA was checked and final obturation of the root canal was done with gutta-percha using lateral condensation technique and the access cavity was sealed with Glass-ionomer restorative material (GC, Type II GIC). Coronal restoration of the fractured crown was done with light cure composite resin material or the acrylic jacket crown. The children were recalled at 3, 6, 9 and 12-month periods and the teeth were assessed clinically and radiographically.

Clinical assessment parameters at recall visit [28,32,33]

- Pain or discomfort immediately after or since root canal obturation
- Tenderness to palpation/Percussion
- Signs of mobility
- Obvious signs of abscess or sinus formation

Criteria for radiographic assessment

Periapical radiographs were assessed and recorded as successful, uncertain outcome or failure based on the criteria published by the European society of Endodontology (1994).[34]

Successful

- Radiographic evidence of normal periodontal ligament space
- Decrease in size of the periapical lesion as compared with preoperative radiograph
- No evidence of inflammatory external root resorption

Uncertain outcome

- If the periapical radiolucent area remained the same and had not diminished in size

Failure

- Evidence that an existing periapical lesion had increased in size
- Evidence of a new lesion, that had appeared subsequent to the placement of the root filling
- Signs of continuing root resorption or hypercementosis.

Evidence of hard tissue formation and root growth were also checked to find out the efficacy of MTA in induction of root end closure and root growth.

Treatment was carried out by one investigator but two examiners independently assessed the radiographs using magnification by a factor of two. At the end of the study both examiners met and in cases of disagreement tried to obtain a uniform decision. The data were entered into a computer software package (SPSS, Version 10.1, SPSS Inc., Chicago, IL, USA). Results were tabulated and descriptive statistics and non parametric test (Wilcoxon signed-rank test) were used to analyze the data. For the graphical presentation of the results Microsoft Excel was used.

RESULTS

Clinical findings

The frequency of preoperative and post-operative signs and symptoms was shown in Figure 1. In most of the cases the pre operative signs and symptoms reduced completely on completion of pulp therapy ($p<0.01$). Pain and pain on percussion developed in 1 case (3.3%) at 3 month and 6 month ($p>0.05$) which was associated with supra eruption of intruded tooth with occlusal interference and subsided after relieving the occlusion and was free of pain for the remaining review period. Mobility reduced in 6 cases out of 8 cases with treatment and one tooth showed grade I mobility at 3 and 6 month review which was associated with supra erupted teeth.

At 9 and 12 month, no negative clinical signs and symptoms were present. The clinical success rate was 96.7%, at 3 and 6 months and 100% at 9 and 12 months (Table1).

Radiographic findings

The frequency of preoperative and post-operative radiographic findings was shown in Figure 2. Widening of PDL space was present in 6 cases (20%) preoperatively, in none after the completion of pulp therapy ($p<0.01$). Mild

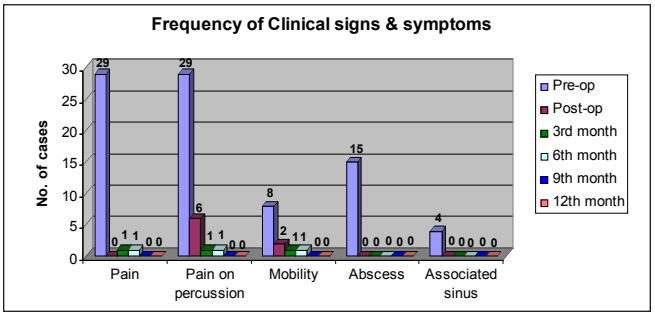

Figure 1. Graph showing the frequency of clinical signs & symptoms

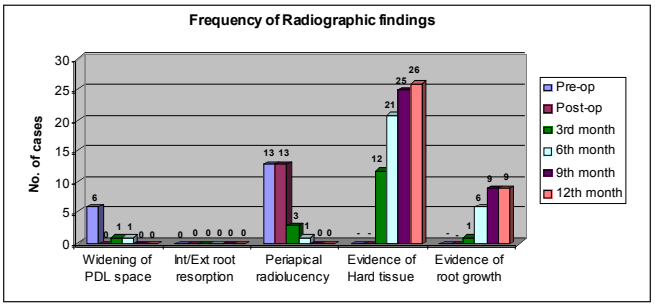

Figure 2. Graph showing the frequency of radiographic findings

widening of PDL space was present in 1 case at 3 and 6 month ($p>0.05$) which was associated with the supra erupted teeth with occlusal interference. Periapical radiolucency was present in 13 cases preoperatively which reduced completely in 10 cases with treatment and reduced in size in 2 cases (6.6%) and remained same in 1 case (3.3%) at 3 month review, and at 6 months review only one tooth (3.3%) showed periapical radiolucency ($p>0.05$). Complete absence of periapical radiolucency (Figure 3) was seen in all the cases for the rest of the study period ($p<0.01$). The mean healing period of periapical radiolucency was 3.92±1.89 months.

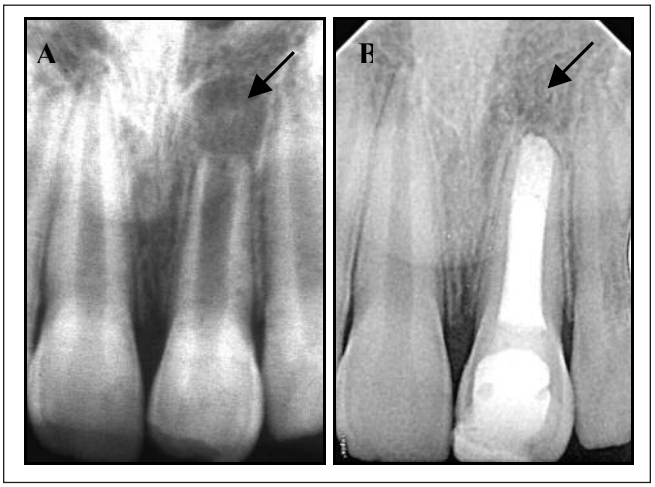

Figure 3. Radiographic pictures showing the healing of periapical radiolucent lesion. **A.** Preoperative **B.** 12 month follow up

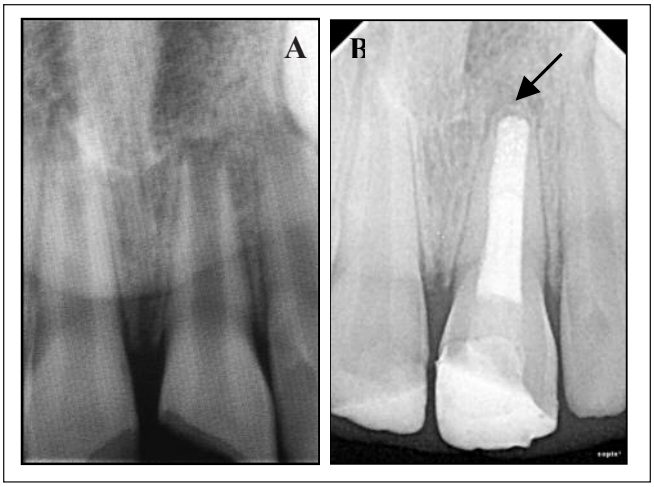

Figure 4. Radiographs showing root end closure with hard tissue formation. **A.** Preoperative **B.**12 month follow up

The radiographic evaluation showed a success rate of 96.7 % and 3.3% uncertain outcome at 3 months and 6 months and 100% at 9 and 12 months review. (Table 1)

Evidence of hard tissue formation (Fig 4) was present in 26 cases (86.6%) and root growth (Fig 5) was present in 9 cases (30%) at 12 months review. The mean time period for hard tissue formation was 5.85 ± 2.59 months and for root growth was 6.42 ± 2.07 months (Table 2)

Relation between the stages of root development and hard tissue formation, and stage of root development and root growth was shown in Table 3. Greater percentage of hard tissue formation (94.11%) and root growth (41.17%) was noticed in stage 4, followed by stage 3 (87.5% & 25%) and stage 5 (60% and no root growth). No statistically significant relationship (p>0.05) was noticed between the stage of root development and hard tissue formation and root growth. Similarly there was no statistically significant relationship (p>0.05) between the level of placement of MTA and hard tissue formation, and the level of placement of MTA and root growth (Table 4).

The histological evaluation of the extracted decalcified root fragment showed the root end closure which was at the progressive stage with the formation of fibrous connective tissue in apical region undergoing calcification with the presence of homogenous eosinophilic calcified areas exhibiting incremental lines adjacent to differentiating cells in the fibrous connective tissue which was suggestive of cementum (Figure 6).

DISCUSSION

Numerous procedures and materials have been recommended to manage teeth with immature apices. The procedures include apexogenesis for vital young permanent teeth, and apexification for non-vital young permanent teeth.[35]

The present study was undertaken to test the efficacy of a new material mineral trioxide aggregate currently suggested for use in multiple endodontic procedures including one visit apexification procedure. MTA was selected as apexification medicament because of its benefits over calcium hydroxide. White MTA (Angelus Branco, Angelus, Brazil) was the material of choice for the present study because of the earlier reports of discoloration of teeth with the use of grey MTA.[9,28,36]

Sample selection for apexification was done following the criteria recommended by Walton and Torabinejad,[1] and the teeth with Moorrees[27] root development stages 3-5 were included. Treatment followed a standard non-surgical root

Table 1. Clinical and Radiographic outcome

	Clinical outcome		Radiographic outcome		
	Success	Failure	Success	Uncertain outcome	Failure
3 month	96.7%	3.3%	96.7%	3.3%	0
6 month	96.7%	3.3%	96.7%	3.3%	0
9 month	100%	0	100%	0	0
12 month	100%	0	100%	0	0

Table 2. Radiographic assessment of Hard tissue formation & Root growth

Time period	Hard tissue formation (No. of teeth)	Root growth (No. of teeth)
3 month	12/30 (40%)	1/30 (3.33%)
6 month	21/30 (70%)	6/30 (20%)
9 month	25/30 (83.33%)	9/30 (30%)
12 month	26/30 (86.66%)	9/30 (30%)
Mean time (months)	5.85±2.59	6.42±2.07

Table 3. Stage of root development Vs Hard tissue formation and root growth

Stage of root development	No. of teeth	Hard tissue Formation (12m)		Root growth (12m)	
		No. of teeth	Percentage	No. of teeth	Percentage
3	8	7	87.50%	2	25%
4	17	16	94.11%	7	41.17%
5	5	3	60%	0	0

Table 4. Level of MTA Vs Hard tissue formation and Root growth

Level of MTA	No. of teeth	Hard tissue Formation (12m)		Root growth (12m)	
		No. of teeth	Percentage	No. of teeth	Percentage
At the apex	25	22	88%	5	20%
Short of apex	1	1	100%	1	100%
Beyond apex	4	3	75%	3	75%

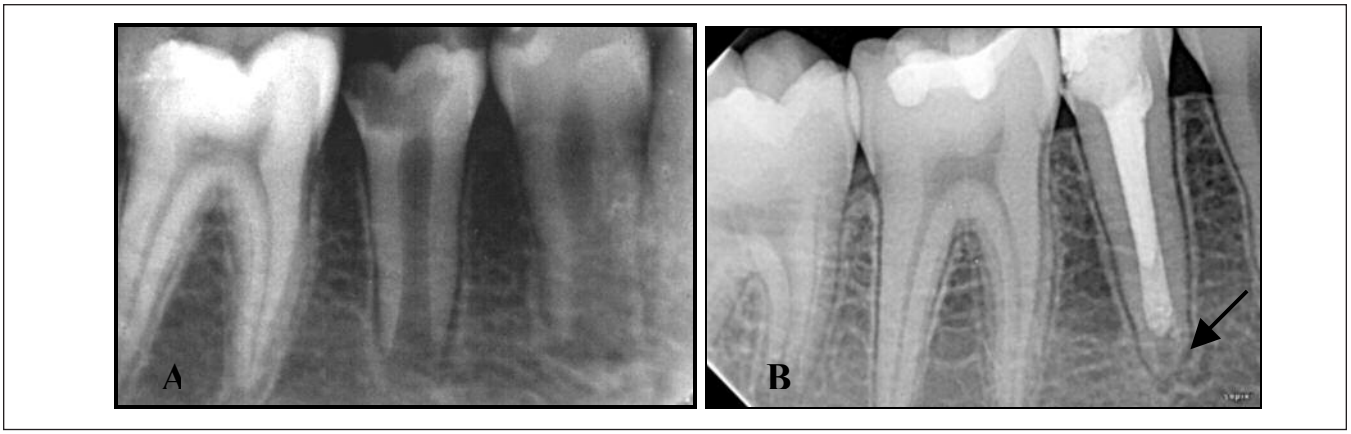

Figure 5. Radiographs showing the root growth **A.** Preoperative **B.**12 month follow up

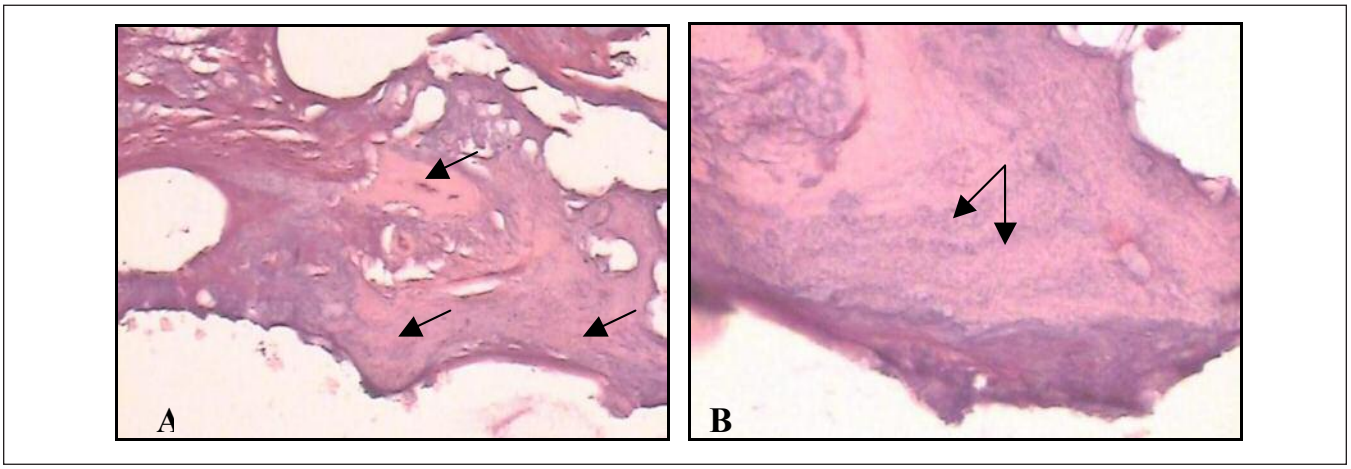

Figure 6. Histological pictures of apical region of extracted root fragment. **A.** Fibrous connective tissue in the apical region undergoing calcification (10X). **B.** Homogenous eosinophilic calcified areas exhibiting incremental lines suggestive of cementum (40X)

canal treatment protocol. Canals were prepared to receive the MTA apical plug by optimal cleaning as recommended by Weine [37] by using effective irrigants like chlorhexidine and dried with wide paper points. In the present study sodium hypochlorite was not used as an irrigant because it can cause tissue necrosis when reached beyond the apex and it is difficult to limit the depth of irrigation.[18,38] Prior disinfection with calcium hydroxide dressing for one week was not done as it was done in previous studies to rule out the role of calcium hydroxide and to assess the role of MTA alone in inducing the hard tissue.[38] MTA apical plug was placed with help of MTA endo carrier (Dentsply) and endodontic plugger. For accurate placement of MTA plug, special instruments like MTA endo gun and operative microscope for better visualization were recommended by some authors.[28]

During clinical and radiographic assessment, most of the preoperative signs and symptoms reduced with endodontic treatment. Pain, pain on percussion, grade I mobility and mild widening of periodontal ligament space was noticed in 1 tooth (3.3%) at 3 and 6 months ($p>0.5$) which was associated with supra eruption and occlusal interference and was reduced by relieving occlusal interference. None of the teeth showed any signs of abscess or associated sinus tract following the placement of MTA till the last evaluation period (12 months) which was similar to the earlier reports.[28,39,40,41]

The periapical radiolucency was present in 3 cases at 3 month and in 1 case at 6 month follow up, radiographically it was considered as successful outcome in 2 cases since the size of periapical radiolucency was decreasing in comparison with preoperative radiograph and in 1 case it was uncertain outcome as the size of the periapical radiolucency remained the same. The mean healing period of periapical radiolucency in the present study was 3.92±1.89 months which is comparable to the results of Pradhan *et al* [33] (4.6±1.5 months). The healing of periapical lesions can be attributed to biocompatibility, sealing ability, reduced micro leakage and antimicrobial properties of MTA cement.[20,22,33,42]

The current study showed 100% clinical and radiographic success rate at the end of 12 month follow up period which was similar to that of El Meligy and Avery[32] (100% for MTA and 87% $Ca(OH)_2$) and was slightly greater to that of Sarris and Tahmassebi [28] (clinical 94.1% and radiographic 76.5%) and other studies.[39,40]

Evidence of hard tissue formation (fig 4) was seen in 26 cases (86.6%) at 12 months which were comparable to the

results of the studies done by Pradhan and Chawla *et al* [33] (70% with MTA &100% with $Ca(OH)_2$), Fellippe *et al* [38] (100%). In the present study, the mean time period for hard tissue formation was 5.85±2.59 months; where as Pradhan *et al* [33] reported a mean time period of 3.0±2.9 months. The probable reason for variation could be due to factors like age, stage of root development, variation in periapical tissue health, healing capacity of the individual and other local and systemic factors which may play a role.

Evidence of root growth (fig 5) was noticed in 9 cases (30%) and the mean time taken for root growth was 6.42±2.07 months, which was in accordance with Sarris et al[28] who reported the continued root development and hard tissue barrier formation over the MTA. In the present study, the stage of root development as well as the level of MTA does not show significant difference in hard tissue formation and root growth which was similar to the earlier reports.[12,38,43,44,45]

In the present study, the histological finding confirmed the induction of root end closure with the presence of homogenous eosinophilic calcified areas exhibiting incremental lines adjacent to differentiating cells in the fibrous connective tissue, suggestive of cementum, which is still under progressive stage (fig 6). This was in accordance with the results of Pittford and Torabinejad *et al* [43,46] and Felippe *et al* [38] .Even though radiographically complete root end closure was seen, histologically it was still under progressive stage suggesting that the nature, structure and amount of hard tissue formed can be confirmed only by the histological evaluation. But it is practically difficult to follow the histological method in human studies. Due to practical difficulty histological evaluation was done for one tooth and only clinical and radiographic evaluation was taken into consideration for the assessment of efficacy of MTA.

The proposed hypothesis to explain the ability of MTA in the hard tissue barrier formation was its mechanism of action similar to that of calcium hydroxide. The MTA which is rich in tricalcium oxide is converted to calcium hydroxide on contact with tissue fluids. The calcium hydroxide separates into Ca and hydroxyl ions resulting in increased pH and release of Ca ions which may cross cell membrane by depolarization or activation of membrane bound calcium channels. The released Ca ions plays important role in reparative process than hydroxyl ions.[47,48] The high pH of MTA is known to activate alkaline phosphatase and antibacterial activities.[33] Calcium ions are necessary for the differentiation and mineralization of pulp cells,[49] and the presence of large quantities of calcium ions in-vivo could activate ATP, which plays a significant role in the mineralization process.[50] The Ca ions react with carbon dioxide in the tissues forming calcium carbonate in the form of calcite crystals.[51,52,53] Fibronectin accumulates with these calcite granulations, which allows cellular adhesion and differentiation to occur and a hard tissue bridge formation.[54] The presence of high calcium concentration further increases the calcium-dependent pyrophosphatase,[55] thus achieving asepsis of lesions and initiating the process of bone healing.[33] MTA generally induces an osteogenic phenotype like alkaline phosphatase, osteonidogen, osteonectin and osteopontin.[56] In the presence of MTA, human gingival fibroblasts (HGF) have been shown to behave similarly to periodontal ligament fibroblasts and express genes indicative of osseous repair and cementogenesis.[56,57]

In the present study, MTA showed its ability to induce root end closure (86%) and root growth (30%) and it can be recommended as an apexification agent. The limitations of the present study were smaller sample size and limited follow up period. Further studies are recommended with large sample size, even distribution of samples with longer follow up period mainly focusing towards the influence of other factors like viability of periapical tissues, reparative and regenerative ability of the individual, stage of root development, age of the patient, quality of MTA plug with three dimensional evaluation etc., on healing, hard tissue formation and root growth, which will be the focus of future investigation.

CONCLUSION

MTA showed success rate of 100% both clinically and radiographically at 12 months follow up.

MTA showed a greater efficiency in inducing root end closure with hard tissue barrier in 86.6% of cases and root growth in 30% of cases.

No significant relationship was found between stage of root development and hard tissue formation and root growth.

No significant relationship was found between the level of MTA and hard tissue formation and root growth.

Histological finding confirms the hard tissue formation which is suggestive of cementum.

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