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Comparative Study of CH and MTA used in Apexogenesis for Young First Permanent Molars

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ABSTRACT

Objectives: To compare clinical and radiographic outcomes of apexogenesis using mineral trioxide aggregate (MTA) and calcium hydroxide (CH) as pulpotomy agents in carious exposed vital young first permanent molars. **Materials & Methods:** Sixty carious exposed vital mandibular first permanent molars with incomplete formed roots indicated for apexogenesis were selected and randomly divided into two treatment groups for pulpotomy (Group I) 30 for CH, (Group II) 30 for MTA. Clinical and radiographic evaluations were performed after 1, 3, 6, 9 and 12 month period. Success rates were recorded according to selected criteria. An indirect digital radiographic system was used for image processing to record changes in root development and surrounding bone density. **Results:** No statistical significant differences were recorded after one year follow-up although the cumulative clinical and radiographic success rates of molars treated with MTA is significantly higher than that of molars treated with CH. MTA showed statistically significant higher mean rate of root development and density than CH. After 12 months follow-up, there was a statistically significant decrease in mean bone density in relation to baseline data. **Conclusions:** MTA showed clinical and radiographic success as a dressing material for apexogenesis and could be recommended as an alternative for CH. MTA can induce root development at a higher rate than CH following apexogenesis. **Clinical Relevance:** The paper gives information about technique of apexogenesis and materials used saving pulp health and enhancing root development in cariously-exposed young permanent molars.It also provides information about the healingpotential of cariously-exposed vital pulp tissue in immaturepermanent teeth.

Key words: Mineral trioxide aggregate, calcium hydroxide, apexogenesis, root development, bone density.

Introduction

Dental pulp therapy of immature permanent posterior teeth presents a challenge in pediatric endodontics (Kontham *et al*., 2005). Among permanent teeth, first permanent molars were proved the most susceptible to caries. The first permanent molars were found not only to be attacked by caries shortly after eruption, but also the percentage of affection increased steadily with age. The reason for this high caries susceptibility was most probably due to the inherent deep occlusal fissures which permit the collection of great numbers of bacteria that could initiate dental caries in the undisturbed fissure depth (Damle, 2006). In many instances, first permanent molars show evidence of the carious attack almost coinciding with their eruption into the oral cavity. Many of these carious lesions were observed to develop rapidly and occasionally progressed from an incipient lesion to a pulp exposure in a 6 month period (Waly *et al*., 1990). Carious exposures in immature teeth, causing irreversible pulp tissue damage, can arrest root development which negatively influence the long-term prognosis of tooth retention (Witherspoon, 2008). Thus, the purpose of treating such immature teeth is to maintain pulp vitality and hence allow continuation of root development and normal apical closure. This approach is known as apexogenesis (Holland *et al*., 2008). Because pulp is necessary for the formation of dentine, the loss of vitality in young permanent teeth before completion of root formation leaves a thin weak root that is prone to fracture and difficult to beendodontically managed (Kansal *et al*., 2011). With the introduction of calcium hydroxide (CH), a new era in vital pulp therapy began where it became the standard pulpotomy agent for immature permanent teeth. The alkaline pH induced by CH not only neutralizes lactic acid from osteoclasts, thus

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preventing dissolution of the material components of dentine, but can also activate phosphatases, which play an important role in hard tissue formation. CH serves to maintain the vitality of radicular tissue until apexogenesis is complete. Despite the long history of using CH dressing in different forms of vital pulp therapy, the issue is still controversial. This is because of the caustic actions of CH. It does not adhere to dentin, and will dissolve over time. Moreover the hard tissue bridge under CH has many imperfections and tunnel defects that may permit micro leakage (Barrieshi-Nusair *et al*., 2006; Alaçam *et al*., 2009). Recently, with the development of materials that are not biocompatible but also bio-inductive, the emphasis has shifted from mere preservation to regeneration of the remaining pulp tissue. One such material, which has shown immense potential for regeneration, is mineral trioxide aggregate (MTA). MTA was developed with the purpose of serving as an apical root-end filling material, but it has also proven to be successful in vital pulp therapy procedures. Its principle components are tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicate oxide. It also contains oxides of iron and magnesium and bismuth oxide is added for radio-opacity (Dammaschke *et al*., 2005; Parirokh and Torabinejad, 2010). MTA is a biocompatible material and its sealing ability is better than that of amalgam or zinc oxide-eugenol. Furthermore, its ability to stimulate cytokine release from bone cells has been demonstrated, including that it actively promotes hard tissue formation (Sari and Sönmez, 2006; Aeinehchi *et al*., 2007; Moretti *et al*., 2007; Moretti *et al*., 2008). Thus this study is carried out to compare clinically and radiograohically the dental pulp response when CH and mineral tri-oxide aggregate used as pulpotomy agents in young permanent teeth.

Material and Methods

This clinical trial was performed over 15 months. Study subjects (aged 7-8 years old) were selected from the outpatient clinic of the Pedodontic Department, Faculty of Oral and Dental Medicine, Cairo University. Subjects were recruited from both genders. A detailed medical history was taken from parents; any subject proved to have a medical condition that contraindicated the use of the intended procedures was excluded. Furthermore, a periapical radiograph of the selected tooth was taken prior treatment.Criteria for teeth selection were as follows: symptomatic/asymptomaticvital immature restorable first permanent molars with clinical carious exposure of the pulp and presence of bleeding upon exposure with no sinus tract, soft tissue swelling, tenderness to percussion or palpation, root resorption, mobility or peri/inter radicular radiolucencies. The treatment was explained to the parents and appropriate informed consents were obtained.Prior to commencing treatment, subjects used 0.2% chlorhexidine mouthwash for 30 sec to reduce bacterial flora in the oral cavity. The designated tooth was anaesthetized and isolated. Caries and roof of the pulp chamber were removed using a(#330) high speed pear shaped tungsten carbide bur and high-speed handpiece with coolant. The pulps were amputated to the orifice level using a long-shank diamond round bur. Haemostasis was achieved by gentle placement of a moistened cotton pellet over amputated pulps for 5 min. The selected cases were divided into two treatment groups. In Group I [30 molars]: pure calcium hydroxide (A-Dent) powderwas mixed with distilled water on a sterile glass slab. After the pulp chamber dried, the paste was placed covering the root orifices. A protective layer of glass ionomer was placed over the CH prior to restoration with a stainless steel crown.

In Group II [30 molars]: mineral trioxide aggregatepaste was prepared according to the manufacturer's instructions. A layer of MTA was placed over the amputated pulps and was gently adapted to the dentinal walls using a cotton pellet. A wet cotton pellet was placed over the MTA, and the tooth was temporized with IRM. On the following day, the tooth was re-anaesthetized and isolated; then IRM was removed and MTA was checked by blunt probing to insure that it had completely set. A layer of glass ionomer was placed over the MTA prior to restoring the tooth with a stainless steel crown. The children were recalled after one, three, six, nine and twelve months post-treatment. A recall sheet was made for every patient.The chemical composition and the manufacturers of the materials used in this study are presented in table 1.

Clinically and radiographically teeth were evaluated according to (Waly *et al*., 1990; Aeinehchi *et al*., 2007; Kalaskar and Damle, 2004; Guelmann *et al*., 2005a; Sabbarini *et al*., 2005); where teeth were scored as clinical success if they had no: pain, tenderness to percussion, gingival inflammation, draining sinus or pathologic mobility. An indirect digital image radiographic system; the DBS-Win software, a part of a recently introduced Vista Scan System* was applied for root development assessment.

Digital images were taken prior-treatment, immediately post-treatment and at each recall visit using a standardized parallel technique (exposure parameters: 70 KVP, 8 mA for 0.04 seconds), an XCP film holder** and an individually constructed radiographic acrylic template to reproduce the same angulation and position of sensor when taking the follow up radiographs. Teeth were scored as radiographic success if showed no: radiolucencies, internal or external root resorption, and periodontal ligament space widening. An additional sign of success was continuation of root development with an apical closure. Linear and Densiometric radiographic measurements were recorded from the standardized radiographs [fig. 1 and 2].

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Table 1: The chemical composition and the manufacturers of the materials used in this study

Materials	Composition	Manufacturer	Lot #
Fuji II LC	**Powder:** Fluro alumino silicate glass **Liquid:** Polyacrylic acid 20–30% 2-HEMA 30–35% Distilled water 20–30% Initiator Urethane dimethylacrylate < 10 Camphorquinone < 1	GC Corporation Tokyo, Japan	250751
3M stainless steel	3M™ ESPE™ UNITEK™ stainless steel crowns	3M ESPE Dental Products, Saint Paul, Minnesota	N155749, N170175, N193318
Pro Root MTA	**Powder:** Di-calcium silicate Tri-calcium aluminate Tetra-calcium-alumino-ferrite Calcium sulfate dihydrate Bismuth oxide **Liquid:** Distilled water	Angelus- Londrina, PR, Brazil	7854
Calcium Hydroxide	**Powder:** Calcium oxide hydrated Liquid: Distilled water	A Dent	---------
IRM ZOE	**Powder:** Zinc oxide 69.0% White rosin 29.3% Zinc acetate 1.0% Zinc stearate 0.7% **Liquid:** Eugenol 85% olive oil 15%	DENTSPLY Caulk	610007

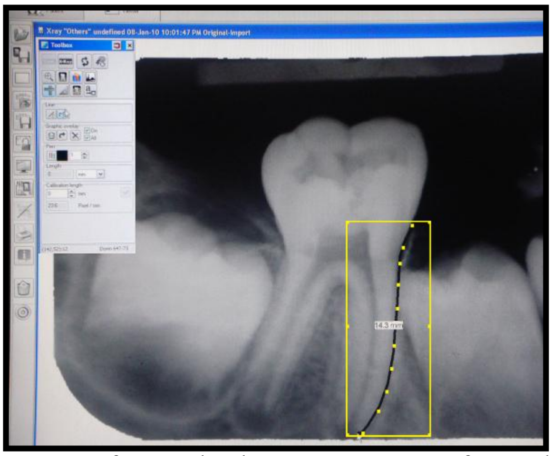

Fig. 1: Linear radiographic measurement for root development assessment of a mandibular 1st permanent molar with incompletely formed root prior to treatment using vista scan imaging system

Fig. 2: Densiometric radiographic assessment of changes in bone density surrounding a mandibular 1st permanent molar with incompletely formed root prior to treatment.

McNemar's Chi-square (x^2) test" was used for studying the comparisons between the different qualitative variables. The differences between values recorded at each examination period in relation to base line data rather than absolute values were used for statistical analysis using Paired t-test. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with SPSS 16.0 (SPSS, Inc., Chicago, IL, U.S.A.) for windows.

Results:

CH showed a clinical and radiographic success rate of (93.1%, 85.7%, 88.5% and 92%)after 1, 3, 6 and 9 months respectively. At 12 month follow up period, CH apexogenesis showed a success rate of 100%as no signs or symptoms of failure have been reported. MTA apexogenesis showed a clinical and radiographic success rate of (96.4%- 92.9%, 92.9% - 92.9% and 92.6% - 92.6%) after 1, 3 and 6 months respectively. At 9 and 12 months follow up periods, the success rates were (100%) as all the cases that attended the 9 and 12 months follow up were free from any signs or symptoms of failure [fig. 3].The results showed that the cumulative clinical and radiographic success rates of apexogenesis using MTA is significantly higher than that with CH yet no statistical significant differences were recorded after one year follow up [table 2].

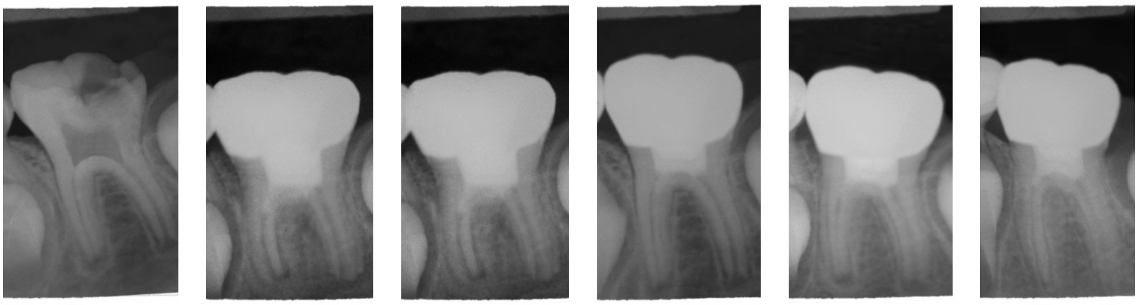

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Fig. 3: a) Pre-operative periapical radiograph of a mandibular right first molar of a 7-year-old patient, b) immediate post-operative radiograph afterapexogenesis with MTA, c) 3 month follow-up radiograph, d) 6 month follow-up radiograph, e) 9 month follow-up radiograph, f) 12 month follow-up

Table 2: Cumulative clinical and radiographic success rates of first permanent molars with incompletely formed roots treated with calcium hydroxide and mineral trioxide aggregate apexogenesis after one year follow up.

	Ca (OH)2 Mean ± SD	MTA Mean ± SD	*P*-value
Clinical success rate	91.9 ± 5.4	96.4 ± 3.6	0.035*
Radiographic success rate	91.9 ± 5.4	95.7 ± 3.9	0.092

* *Significant at $P \leq 0.05$*

Root Development Assessment:

Linear Measurement:

No statistically significant difference between mean linear measurements of the two groups throughout the follow-up period of 12 months [table 3].

Table 3: Means and standard deviation values of linear measurements of root development of first permanent molars treated with calcium hydroxide and mineral trioxide aggregate apexogenessis.

Group Period	Ca $(OH)_2$ Mean ± SD	MTA Mean ± SD	*P*-value
Pre-operative	14.34 ± 0.9	14.28 ± 0.8	0.724
1 m	14.49 ± 0.8	14.40 ± 0.8	0.599
3 m	14.60 ± 0.9	14.65 ± 0.8	0.809
6 m	14.88 ± 0.9	14.95 ± 0.8	0.704
9 m	15.13 ± 0.9	15.25 ± 0.7	0.524
12 m	15.37 ± 0.8	15.55 ± 0.7	0.313

** Significant at P ≤ 0.05*

Rates of root development: The rate of root development was calculated as:
12 months measurement – Pre-operative measurement
Time (12 m)

Means of linear measurements between values recorded at each examination period in relation to base line data in each group were calculated to determine which time interval showed significant differences within each group during the follow up period. After 1, 3, 6, 9 and 12 months, there was a statistically significant increase in mean linear measurements in relation to baseline data in both groups, however MTA group showed statistically significantly higher mean rate of root development than CH group [fig. 4].

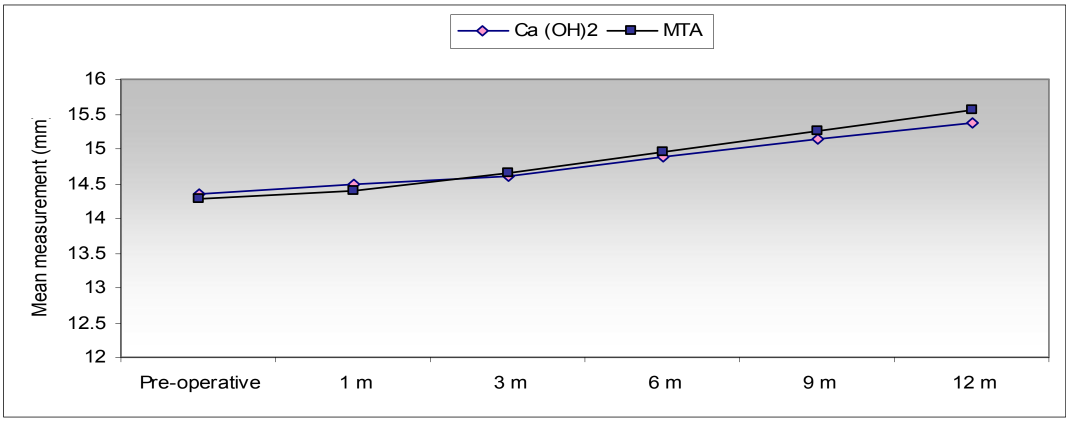

Fig. 4: Histogram shows the mean differences and standard deviation values for the linear measurements changes of root development in relation to the base line data of first permanent molars treated with calcium hydroxide and mineral trioxide aggregate apexogenesis

Density measurement:

There was no statistically significant difference between mean density measurements of the two groups after 1 month, 3, 6 and 9 months. After 12 months, MTA group showed statistically significantly higher mean density than CH group [table 4].

Table 4: Means and standard deviation values of the changes in density measurements in the periapical areas of first permanent molars treated with calcium hydroxide and mineral trioxide aggregate apexogenesis.

Group Period	Ca $(OH)_2$ Mean ± SD	MTA Mean ± SD	*P*-value
Pre-operative	0.016 ± 0.003	0.016 ± 0.003	0.774
1 m	0.015 ± 0.003	0.015 ± 0.003	0.436
3 m	0.014 ± 0.003	0.014 ± 0.003	0.383
6 m	0.012 ± 0.003	0.013 ± 0.003	0.119
9 m	0.010 ± 0.002	0.012 ± 0.003	0.063
12 m	0.008 ± 0.002	0.010 ± 0.002	0.008*

** Significant at P ≤ 0.05*

Changes by time in CH and MTA group:

Means of density measurements between the values recorded at each examination period in relation to base line data were determined to show which time interval showed significant difference within each group during the follow up period. After 1, 3, 6, 9 and 12 months, there was a statistically significant decrease in mean density measurements in relation to base line data [fig.5].

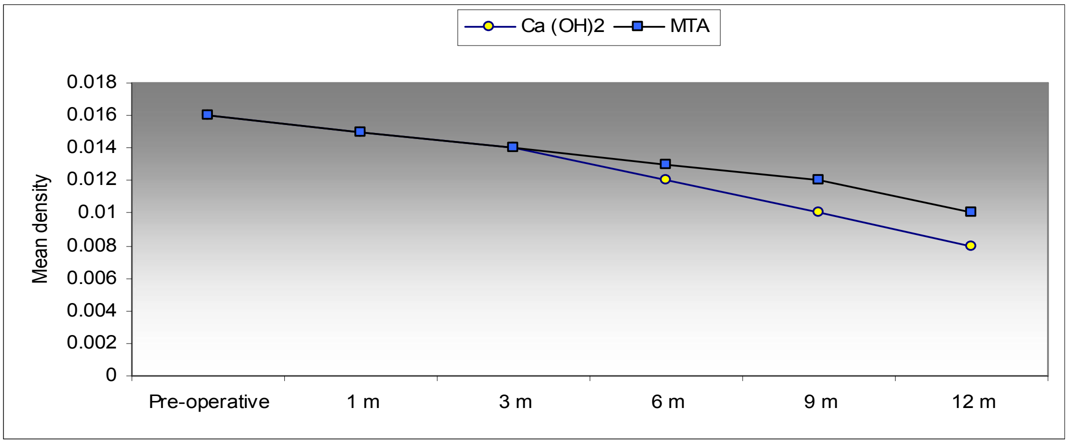

Fig. 5: Histogram showing the mean differences and standard deviation values for the density measurements changes of root development in periapical areas in relation to the base line data of first permanent molars treated with calcium hydroxide and mineral trioxide aggregate apexogenesis.

Discussion:

This clinical trial was carried out aiming to determine a pulp capping agent exhibiting the best clinical and radiographic success rates. Children were selected with an age range of (6-8 years) keeping in mind the feasibility of collecting the required sample restricted to cariously exposed first permanent molars with unformed apices within a specified time period. Materials used were selected to be representative to their mode of action. CH was selected as a pulpotomy agent because it is currently considered the standard therapeutic agent for apexogenesis procedures in immature permanent teeth. MTA, a biocompatible material, selected because of its predictable bioinduction of dentine formation. Indirect digital image radiographic system; the DBS-Win software, which is a part of the recently introduced Vista Scan System was chosen to measure the changes in the treated cases because it facilitates both qualitative and quantitative visualization of even minor changes. It has proven to be sensitive, reliable and accurate in addition to the easy access of image processing which enhance the diagnostic value and facilitate the diagnostic interpretation (Analoui and Buckwalter, 2000;Arenson *et al*., 2000; Analoui, 2001a;Analoui, 2001b; Lehmann *et al*., 2002; Yalcinkaya *et al*., 2006). In this study MTA apexogenesis resulted in higher clinical and radiographic success rates (96.4%, 95.7%) than that reported by CH apexogensis (91.9%, 91.9%) throughout the total follow up period yet no statistical significant differences were reported. This may be due to the fact that MTA prevents microleakage, biocompatible and promote regeneration of the original tissues when placed in contact with the dental pulp. Also the fact that MTA hardens in the presence of moisture should be emphasized, which may have evoked a better sealing of pulp chamber, and consequently better results, as compared with CH. This is in agreement with Gupta *et al*.,1999 and El-Sherbeiny *et al*., 2003 who reported that CH showed worse results than MTA due to the non setting nature of CH, difficulty of packing and its known initial caustic effect on vital tissues. In addition, Briso *et al*., 2006 reported that the initial effect of CH is destructive, yielding chemical injury caused by hydroxyl ions, which present highly alkaline pH, leading to superficial necrosis of the pulp with mild irritation. This area of necrosis, when the pulp is not protected by a good marginal sealing achieved with restorative materials, may yield clinical or radiographic failures. The results are concomitant with El-Meligy and Avery, 2006who reported that MTA showed clinical and radiographic success as a pulpotomy agent in immature permanent teeth and seemed to be a suitable alternative to CH; however there was no statistically significant difference between the two treatment groups. Although the cumulative clinical and radiographic success rates of young permanent molars treated with MTA is significantly higher than that of molars treated with CH, the outcomes of MTA and CH apexogenesis in the two treatment groups were comparable. This may be attributed to the nature of the CH used. Calcium hydroxide, used in its pure powder form and mixed with distilled water to gain its highest pH value, thus providing close opposition of powder and pulp tissue. This agrees with Pacios *et al*., 2004 and El-Tawil *et al*., 2005 who stated that the CH-water combination showed higher pH value than other vehicles used to prepare the paste. According to Jabbarifar *et al*., 2004, Chacko and Kukirose., 2006 and Percinoto *et al*., 2006, healing of the dental pulp is not exclusively dependent on the supposed stimulatory effect of a particular type of medicament but it is directly related to the capacity of both the dressing and definitive restorative material to provide a biological seal against immediate and long-term micro leakage along the entire restoration interface. In the current study, stainless steel crowns are chosen to provide optimal coronal seal in the two treatment groups. This study's MTA group showed two teeth with pathological signs and symptoms and they were regarded as failures at the 12 month evaluation. However in the CH group four teeth showed signs and symptoms of failure at the 12 month evaluation. Thus possible failures in sealing may have been involved in the treatment outcomes achieved. The results of the current study also revealed sustained increase in root development and bone density throughout the follow up periods. The results showed no statistically significant differences between mean linear measurements or between mean density measurements of the two treatment groups after 1, 3, 6 and 9 months. However after 12 months, MTA cases showed statistically significantly higher mean density than CH cases. This could be explained by the fact that both materials have demonstrated similar ability to induce hard tissue formation in pulpal tissue when used as a pulpotomy material. In addition, pulp in both groups remains vital after amputation of the coronollay inflamed pulp and dressing the wounded surface of the radicular pulp with a medicament that promote healing where the alkaline pH prevents the development of infection and cause bacterial destruction. Like CH, MTA also has a high pH (12.5) that causes denaturation of adjacent cells, tissue proteins and some bacteria in the wound area. This clinical study gives attention to the effect of MTA, used as a pulpotomy agent in young permanent molars through linear and bone density assessments as compared to CH. However earlier studies compared the efficacy of these two pulp capping agents on animals. Holland *et al*., 1999b compared the properties of MTA to those of CH and found that CH acts on dentine in the same way as it does on pulp tissue and observed mineral crystals in the tubules. It was believed that these crystal deposits in the dentinal tubules may be CH. The mineral trioxides particles particularly those of calcium, react with tissue fluids and form calcium crystals similar to those observed with CH.Tziafas*et al*., 2002 stated that although the exact mechanism by which MTA induces hard tissue formation is not completely understood, there are indications that the mechanism of initiation of reparative dentinogenesisafter capping with MTA and CH cement is similar. Moreover Aeinehchi *et al*., 2003 reported that a thicker dentinal bridge and more frequent presence of odontoblastic layer was evident when teeth were capped with MTA compared to CH. Histological evaluation in an animal study by Chacko and Kurikose, 2006 has shown that MTA stimulates reparative dentin formation, with thick dentinal bridging, minimal inflammation, and nominal hyperemia. The net result is that vital pulp therapy with MTA produces negligible pulpal necrosis. Both CH and MTA showed increase in the rate of root formation; however MTA showed statistically higher mean rate of root development than CH. This may be attributed to their similar mechanism of action in addition to the ability of MTA to stimulate cytokine release from bone cells, indicating that it actively promotes hard tissue formation rather than being inert as mentioned by El-Sherbeiny *et al*., 2003.This is in agreement with Junn *et al*., 1998 who stated that MTA appeared to induce the formation of a dentin bridge at a faster rate than CH. This is also concomitant with Mitchell *et al*., 1999 who reported that MTA promotes rapid cell growth in vitro. Compared with CH, in animal studies, Farco and Holland, 2001 and Accorinte *et al*., 2008 concluded that MTA consistently induces the formation of dentin at a greater rate with a superior structural integrity. A significant difference was observed between MTA and CH after 30 days. Thus, it appeared that MTA takes advantage in producing healing in a shorter period of time. On the other hand, the results of the present study disagree with Iwamoto *et al*., 2006 who reported no significant difference between MTA and CH regarding hard tissue bridge formation or inflammatory cell response. Whereas Iwamoto *et al*., 2006 used grey MTA; the present study used the white Pro Root® MTA. The composition of both materials is rather different. A significantly higher amount of iron is present in the grey MTA compared with the white, besides the fact that the latter does not contain aluminum and dicalcium silicate. Although Perez *et al*., 2003 has demonstrated that the white MTA is not as biocompatible as the grey version, no significant difference was observed between both MTA versions when used for pulp capping as reported by Iwamoto *et al*, 2006. Thus, this matter still deserves further evaluations to elucidate the concerns raised.

Conclusion:

MTA showed a clinical and radiographic success as a dressing material for apexogenesis and could be recommended as an alternative for CH. Both, MTA and CH showed increase in root development and density in relation to base line data yet, MTA can induce root development at a higher rate than CH following apexogenesis in young permanent teeth.

References

Accorinte, M.R., R. Holland, A. Reis, M.C. Bortoluzzi, S.S. Murata, V. Dezan E Souza and L.D. Alessandro, 2008. Evaluation of mineral trioxide aggregate and calcium hydroxide cement as pulp capping agents in human teeth. J Endod, 34: 1-6.

Aeinehchi, M., B. Eslami, M. Ghanbariha and A.S. Saffar, 2003. Mineral trioxide aggregate (MTA) and calcium hydroxide as pulp–capping agents in human teeth: a preliminary report. IntEndod J, 36: 225-31.
Aeinehchi, M., S. Dadvand, S. Fayazi, and S. Bayat–Movahed, 2007. Randomized controlled trial of mineral trioxide aggregate and formocresol for pulpotomy in primary molar teeth. IntEndod J, 40: 261-267.
Alaçam, A., M.E. Odabaş, T. Tüzüner, H. Sillelioğlu and O. Baygin, 2009. Clinical and radiographic outcomes of calcium hydroxide and formocresolpulpotomies performed by dental students. Oral Surg Oral Med Oral Pathol Oral RadiolEndod, 108(5): 27-33.
Analoui, M., 2001a. Radiographic image enhancement. Part I: Spatial domain techniques. Dentomaxill ofac Radiol, 30: 1-9.
Analoui, M., 2001b. Radiographic image enhancement. Part II: Transform domain techniques. DentomaxillofacRadiol, 30: 65-77.
Analoui, M. and K. Buckwalter, 2000. Digital radiographic image archival, retrieval, and management. Dent Clin North Am, 44: 339-358.
Arenson, R.L., K.P. Andriole, D.E. Avrin and R.G., 2000. Gould. Computers in imaging and health care: now and in the future. J Digit Imaging, 13: 145-156.
Barrieshi-Nusair, K.M., M.A. Hammad and M.A. Qudeimat, 2006. A prospective clinical study of mineral trioxide aggregate for partial pulpotomy in cariously exposed permanent teeth. J Endod, 32: 731-735.
Briso, A.L., V. Rahal, S.R. Mestrener and E.D. Junior, 2006. Biological response of pulps submitted to different capping materials. Bras Oral Res., 20: 219-225.
Chacko, V. and S. Kurikose, 2006. Human pulpal response to mineral trioxide aggregate (MTA): A histologic study. J ClinPaediatr Dent, 30: 203-209.
Damle, S.G., 2006. Morphology of Deciduous Dentition. Text Book of Paediatric Dentistry. 3rd ed, pp: 123-132.
Dammaschke, T., H.U. Gerth, H. Zuchner and E. Schafer, 2005. Chemical and physical surface and bulk material characterization of white ProRoot MTA and two Portland cements. Dent Mat, 21: 731-8.
El–Meligy, O.A. and D.R. Avery, 2006. Comparison of mineral trioxide aggregate and calcium hydroxide as pulpotomy agents in young permanent teeth (apexogenesis). Paediatr Dent, 28: 399-404.
EL–Sherbeiny, M., L.F. Shafie, S.M. Shawkat and F.A.H. EL–Shehaby, 2003. Clinical, radiographic and histological assessment of MTA and calcium hydroxide apexification materials (Human and Animal Study). Cairo Dent J, 19(2): 185-191.
EL-Tawil, S.B., M.A. Rashed, M.S.E. Mostafa and A.A. Mortada, 2005. The effect of low energy laser therapy combined with calcium hydroxide on biostimulation of apical root closure in incompletely formed traumatized upper permanent anterior teeth in Egyptian children. Ph D Thesis, Faculty of Oral and Dental Medicine, Cairo University.
Faraco, I.M.Jr. and R. Holland, 2001. Response of the pulp of dogs to capping with mineral trioxide aggregate or acalcium hydroxide cement. Dent Traumatol, 17: 163-6.
Guelmann, M., F. Fair and E. Bimstein, 2005a. Permanent versus temporary restorations after emergency pulpotomies in primary molars. Paediatr Dent, 27: 478-481.
Gupta, S., A. Shatma and N. Dang, 1999. Apical bridging in association with regular root formation following single–visit apexification: a case report. Quint Int, 30(8): 560-562.
Holland, G., H. Trowbridge and M. Rafter, 2008. Protecting the pulp, preserving the apex. Text Book of Endodontics, Principles and Practice, 4th edn., Elsevier publishers, pp: 21-38.
Holland, R., V. De Souza, M.J. Nery, J.A. OtoboniFilho, P.F.E. Bernabe and E. Dezan Junior, 1999b. Reaction of rat connective tissue to implanted dentin tubes filled with mineral trioxide aggregate or calcium hydroxide. J Endod, 25: 161-166.
Iwamoto, C.E., E. Adachi, C.H. Pameijer, D. Barnes, E.E. Romberg and S. Jefferies, 2006. Clinical and histological evaluation of white ProRoot MTA in direct pulp capping. Am J Dent, 19: 85-90.
Jabbarifar, S.E., A.A. Khademi and D. Ghasemi, 2004. Success rate of formocresolpulpotomy versus mineral trioxide aggregate in human primary molar tooth. J Res Med Sci., 6: 55-8.
Junn, D.J., P. McMillan, L. Bakland and M. Torabainejad, 1998. Quantitative assessment of dentin bridge formation following pulp–capping with mineral trioxide aggregate (MTA). J Endod, 24: 278.
Kalaskar, R.R. and S.G. Damle, 2004. Comparative evaluation of lyophilized freeze dried platelet derived preparation with calcium hydroxide as pulpotomy agents in primary molars. J IndSocPedodPrev Dent, 22: 24-29.
Kansal, N., K. Rajnish, G. Pratibha, J. Rajesh, G. Deepika and G. Harpreet-Singh, 2011. Management of immature teeth by dentin-pulp regeneration: A recent approach. Med Oral Patol Oral Cir Bucal, 16(7): 997-1004.
Kontham, U.R., A.M. Tiku, S.G. Damle and R.R. Kalaskar, 2005. Apexogenesis of a symptomatic mandibular first permanent molar with calcium hydroxide pulpotomy. Quintessence Int, 36(8): 653-7.

Lehmann, T.M., E. Troeltsch and K. Spitzer, 2002. Image processing and enhancement provided by commercial dental software programs. DentomaxRadiol, 32: 264-72.
Mitchell, P.J., T.R. Pitt Ford, M. Torabinejad and F. McDonald, 1999. Osteoblast biocompatibility of mineral trioxide aggregate. J Biomat, 20(2): 167-173.
Moretti, A.B.S., T.M. Oliveira, V.T. Sakai, C.F. Santos, M.A.A.M. Machado, and R.C.C. Abdo, 2007. Mineral trioxide aggregate pulpotomy of a primary second molar in a patient with agenesis of the permanent successor. IntEndod J, 40: 738-745.
Moretti, A.B.S., V.T. Sakai, T.M. Oliveira, A.P.C. Fornetti, C.F. Santos, M.A.A.M. Machado and R.C.C. Abdo, 2008. The effectiveness of mineral trioxide aggregate, calcium hydroxide and formocresol for pulpotomies in primary teeth. IntEndod J; 41: 547-555.
Pacios, M.G., M.L. De la Casa, M.A. De Bulacio and M.E. Lopez, 2004. Influence of different vehicles on the pH of calcium hydroxide pastes. J Oral Sci., 46(2): 107-111.
Parirokh, M. and M. Torabinejad, 2010. Mineral Trioxide Aggregate: A comprehensive literature review-Part I: chemical, physical, and antibacterial Properties. J Endod, 36: 16-27.
Percinoto, C., A.M. De Castro and L.M. Pinto, 2006. Clinical and radiographic evaluation of pulpotomies employing calcium hydroxide and mineral trioxide aggregate. Gen Dent, 54: 258-61.
Pérez, A.L., R. Spears, J.L. Gutmann and L.A. Opperman, 2003. Osteoblasts and MG–63 osteosarcoma cells behave differently when in contact with ProRoot MTA and White MTA. IntEndod J, 36: 564-570.
Sabbarini, J.M.S., A.A. Mohamed, M.M.F. Mounir, N.A. Wahba and O.A.S. El-Meligy, 2005. Comparson of pulpal response following pulpotomy procedure using enamel matrix derivative versus formocresol in primary dentition. MD Thesis, Faculty of Dentistry, Alexandria University.
Sari, S. and D. Sönmez, 2006. Internal resorption treated with mineral trioxide aggregate in a primary molar tooth: 18-month follow-up. J Endod, 32(1): 69-71.
Tziafas, D., O. Pantelidu, A. Alvanou, G. Belibasakis and S. Papadimitriou, 2002. The dentinogenic effect of mineral trioxide aggregate (MTA) in short term capping experiments. IntEndod J, 35: 245-54.
Waly, N.G., N. Soliman, S. EL-Ashry and S. EL-Behery, 1990. A comparative clinical and radiographic study of pulpotomy and pulpectomy in young permanent teeth. PhD Thesis, Faculty of Oral and Dental Medicine, Cairo University Press.
Witherspoon, D., 2008. Vital pulp therapy with new materials: a new directions and treatment perspectives permanent teeth. J Endod, 34: 25-28.
Yalcinkaya, S., A. Künzel, R. Willers, M. Thoms and J. Becker, 2006. Subjective image quality of digitally filtered radiographs acquired by the DürrVistascan system compared with conventional radiographs. Oral Surg Oral Med Oral Pathol Oral RadiolEndod, 101: 643-51.