Sealing Ability of MTA versus Portland Cement in the Repair of Furcal Perforations of Primary Molars: A Dye Extraction Leakage Model

Sherif B. El Tawil[*1]; Norhan A. El Dokky[1] and Dalia Abd El Hamid[2]

[1]Pediatric and Community Dentistry Department, Faculty of Oral and Dental Medicine, Cairo University
[2]Dental Materials Department, Faculty of Oral and Dental Medicine, Cairo University
[*]drsherifbahgat@hotmail.com

Abstract: Aim: The purpose of this study was to compare the sealing ability of MTA versus Portland cement (PC) in the repair of furcal perforations of primary molars (in-vitro study). Materials & Methods: 30 extracted primary molars were divided into four groups after access openings and furcation perforations were prepared in the pulp chamber floor. Group 1 (n=10) in which perforations were repaired with MTA (ProRoot MTA, MTA-Angelus), Group 2 (n=10) in which perforations were repaired with Portland cement, Group 3 (n=5) in which perforations were left unsealed (Positive control) and Group 4 (n= 5) without perforations (Negative control). The seleability of the tested materials was evaluated by the dye extraction method. 1% basic fuchsin dye was applied inside the access cavity of all teeth for 24 hours. The teeth were placed in vials containing 1 ml of concentrated (65 wt %) nitric acid until complete dissolution. The absorbance was read by an automatic microplate spectrophotometer at 545 nm using concentrated nitric acid as a blank the results were statistically analyzed. Results: The results showed that there was no statistically significant difference in the microleakage between MTA and Portland cement repair groups. Conclusions: Portland cement has the potential to be used as a less expensive material alternative to MTA in the repair of perforation site of primary teeth.
[Sherif B. El Tawil; Norhan A El Dokky and Dalia Abd El Hamid **Sealing Ability of MTA versus Portland Cement in the Repair of Furcal Perforations of Primary Molars: A Dye Extraction Leakage Model]** Journal of American Science 2011; 7(12):1037-1043]. (ISSN: 1545-1003). http://www.americanscience.org.

Keywords: Perforation, MTA, Portland cement, dye extraction.

1. Introduction

Although there have been many advances in the prevention of dental caries and the understanding of the importance of preserving natural primary teeth has increased, many teeth are still lost at an early age. Preservation of the primary teeth before the eruption of the permanent ones is desirable since they help to determine the shape of dental arches, maintain the space between teeth, prevent detrimental tongue and speech habits, preserve aesthetics, and maintain chewing function. Hence, carious primary teeth should ideally be restored rather than be extracted (1).

The retention of pulpally involved deciduous tooth in a healthy state until the time of normal exfoliation remains to be one of the challenges for Pedodontist (2). Pulpotomy is the most widely accepted clinical procedure for treating primary teeth with inflammation of the coronal pulp caused by caries with no involvement of the radicular pulp. This procedure helps in maintaining arch integrity by allowing preservation of the teeth that would otherwise be destined for extraction. This technique consists of removing the coronal pulp and healing the radicular pulp with a suitable medicament. The purpose of this procedures is to remove the bacterial infection leaving the treated tooth asymptomatic until its normal exfoliation time (3,4).

Complicated problems may be encountered during pulpotomy treatment. There may be a need for periradicular surgery, sealing perforations (with or without surgery). Perforations in the crown, floor of the pulp chamber (furcation perforations) or 1/3 of the coronal roots are errors that occur when care is not taken during the creation of a favorable access opening. Immediate sealing of these perforations with suitable repair materials lead to successful treatment (5).

In order to gain a good prognosis the repair material should be sealable, biocompatible (non toxic), not polluted with blood, no extrusion of repair material through perforation during condensation, bactericidal, induce bone formation and healing, radiopaque, induce mineralization, cementogenesis and easy in manipulation and of reasonable cost (6-13).

Several materials have been proposed for sealing of perforations. These materials include zinc oxide-eugenol cements (IRM and Super-EBA), glass ionomer cement, resin composites, resin modified glass ionomer (RMGI), and mineral trioxide aggregates (MTA). However, the divergent outcomes have demonstrated that so far no ideal sealing material has been achieved (14).

Mineral trioxide aggregate (MTA) has been regarded as an ideal material for perforation's repair, retrograde filling, pulp capping, and apexification since its introduction in 1993 (15-16). The principle compounds present in MTA are several mineral oxides that are responsible for the chemical and physical properties of this material (17). There are several studies that have demonstrated its excellent sealing ability and biocompatibility (18). Using different leakage approaches such as: fluid filtration technique,(19) dye-leakage model,(20) bacterial leakage model,(21) and dye-extraction leakage method (22).

Experimentally, MTA showed better sealing ability than other materials, such as amalgam (21), zinc oxide-eugenol cement (15), resin-modified glass ionomer cements (20). Microscopic examinations of periodontal tissues after perforations in the furcal area and subsequent sealing with MTA demonstrated repair of the periodontium, and new cementum formation over the material (23). The repair capacity of MTA can in turn be attributed to its antimicrobial properties and high pH (12.5). These characteristic of MTA promote cementum and bone formation (24). However, the elevated cost of this product has not allowed its use in all levels of health attention. Therefore, different studies have compared the components of MTA and Portland cement, a material used in civil engineering, due to their chemical and physical similarity (25-28). As both materials are composed of calcium phosphate, calcium oxide and silica. MTA, however, contains bismuth oxide, an element that provides radiopacity (15).

Taking into account the low cost and apparently similar properties of PC in comparison to MTA, it is reasonable to consider PC as a possible substitute for MTA in endodontic applications and repair of perforations (29-32). In this view, the aim of this study is to compare the ability of MTA and Portland cement (PC) to seal furcal perforations in extracted primary molars using the dye extraction leakage model.

2. Materials and Methods:

Thirty extracted primary molars were used in this study. The teeth were collected from the Outpatient clinic of the Paediatric Dentistry Department, Faculty of Oral and Dental Medicine, Cairo University. Cracked teeth were discarded. After extracting the teeth they were kept in 5% sodium hypochlorite for 30 minutes. They were then cleaned from any debris and washed under tap water and kept in normal saline until next step (33).

Teeth preparation:

The primary molars were amputated 3mm below the furcation area using a tapered diamond stone. Endodontic access cavity was prepared in every molar with a round bur # 2 and the root canal orifices were located (34). The canal orifices and the apical end of each root were etched with 37% phosphoric acid gel (Scotchbond; 3M ESPE Dental Products, St Paul, MN, USA) for 30 seconds, then the Single bond adhesive system (Scotchbond) was applied in 2 consecutive coats and photopoymerized for 10 seconds with LED source. A resin composite Z100 (3M ESPE Dental Products, St Paul, MN, USA) was then used to fill the root canal orifices as well as the apical end of the root and was then photopolymerized for 40 seconds (Table1). Every molar was covered completely including cavity walls and pulpal floor with two successive layers of clear nail varnish in an attempt to increase the marginal seal (28, 35).

Creation of perforations:

A silicone impression material (Express STD 3M ESPE, Dental Products) was mixed according to the manufacturer instructions to provide a matrix that simulated the bony socket. The primary molars were placed into the unset silicone impression material and then removed after polymerization. Artificial perforation was created in the centre of the pulp chamber of each primary tooth with round bur #2 (Dentsply Maillefer, Ballaigues, Switzerland) in low speed handpiece (Fig.1) (35).

Then the teeth were divided into four groups:

Group 1: 10 molars in which the perforations were repaired with MTA cement.

Group 2: 10 molars in which the perforations were repaired with Portland cement.

Group 3: 5 molars in which perforations were left unsealed (Positive control).

Group 4: 5 molars without perforations (Negative control).

Repair procedures and materials:

In group1, the perforation site was repaired with ProRoot MTA (MTA-Angelus) it was mixed according to the manufacturer's instructions, placed with Messing gun and compacted with hand plugger (Figs. 2&3). A cotton pellet moistened with saline was placed in the pulp chamber against the MTA until its setting. (34).

In group 2, the perforation site was repaired with Portland cement. The powder was first refined by silk refiner and sterilized using dry heat at 170° C for 1 hour. One gram of the powder was then mixed with sterile distilled water to produce a homogenous paste. The Portland cement was mixed to a consistency similar to that of the MTA cement and was placed with the same procedure as in group 1. Moist cotton pellet was placed over the repair material and the teeth were kept in 100% humidity for 24 hours to allow the materials to set (34).

Basic fuchsin dye of 1% was applied inside the access cavity of all primary teeth for 24 hours. Then the teeth were placed under running water for 30 minutes to remove all residues of the basic fuchsin dye. (Fig.4) The varnish was removed with Parker blade ♯ 15 (22).

Table (1): The materials used in the study

Material	Manufacturer	Batch no.
Acid etch	3M ESPE,St.Paul,MN (USA)	N 1411008
Single bond adhesive(Scotchbond)	3M ESPE St.Paul,MN (USA)	N 169845
Composite (Z100)	3M ESPE, St.Paul,MN (USA)	N 176309
Silicone impression material(Express STD)	3M ESPE, St.Paul,MN (USA)	N 245822
MTA (ProRoot)	MTA-Angelus (Brazil)	10086

Microleakage Measurement:

The teeth were placed in vials containing 1 ml of concentrated (65 wt %) nitric acid until complete dissolution. (Fig.5). Vials were centrifuged at 9000 rpm for 7 minutes. Two hundred microliteres of the supernatant from each sample was transferred to a 96- well plate. Sample absorbance was read by an automatic microplate spectrophotometer (StatFax-2100, Awareness Technology, Inc. 1935 S.W. Martin Hwy. Palm City, FL 34990, USA) at 545 nm using concentrated nitric acid as a blank (36).

Statistical analysis:

ANOVA test was used to compare the mean of the different groups. Tukey's test was used in the procedure of pair-wise comparisons between the groups when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with SPSS 16.0 (Statistical Package for Scientific Studies, SPSS, Inc., Chicago, IL, USA) for Windows.

Figure (1): Tooth after creating the perforation

Figure (2): Tooth after application of Portland (Top view)

Figure (3): Tooth after application of Portland (Bottom view)

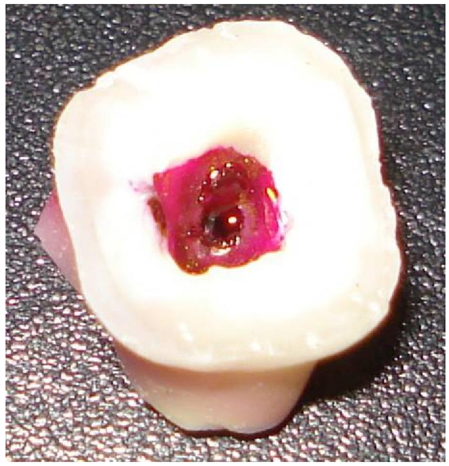

Figure (4): Tooth after application of 1 % basic fuchsin dye.

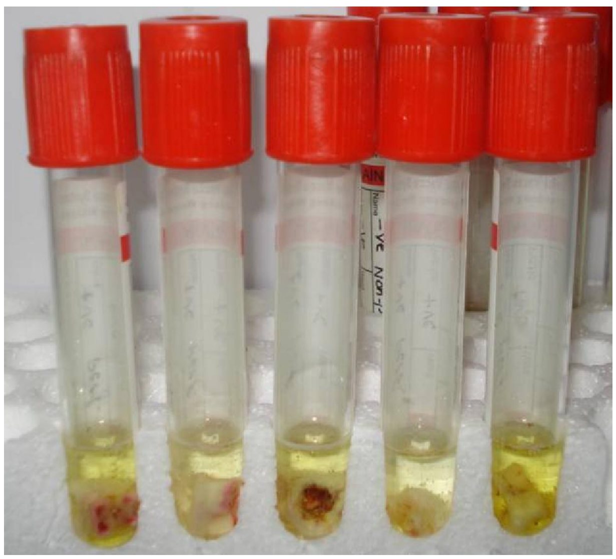

Figure (5): Teeth submerged in concentrated nitric acid.

3. Results:

The data were presented as mean and standard deviation (SD) values in Table (2) and Figure (6). The positive control group showed the highest dye absorbance (0.631 ± 0.223). While, there was no statistically significant difference between the dye absorbance values in the Portland cement repair group (0.278 ± 0.057) and the MTA cement repair group (0.263 ± 0.051). However, the dye absorbance values of both groups were significantly higher than the negative control group (0.134 ± 0.075).

Table (2): Means and standard deviation (SD) of the dye absorbance values for the tested groups

Group	Mean	SD	Rank	*P*-value
Portland cement	**0.278**	**0.057**	**B**	**<0.001***
MTA cement	**0.263**	**0.051**	**B**	
Positive control	**0.631**	**0.223**	**A**	
Negative control	**0.134**	**0.075**	**C**	

*: Significant at P ≤ 0.05, Means with different letters are statistically significantly different according to Duncan's test

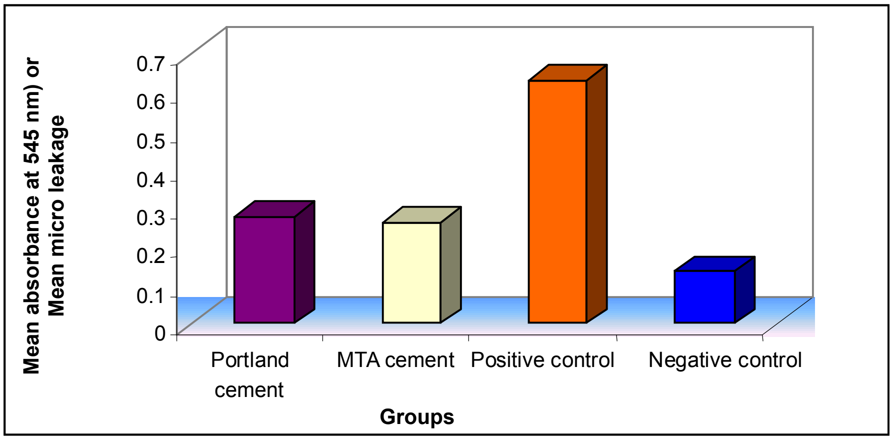

Figure (6): Mean leakage values in the four groups

4. Discussion:

The prognosis of pulpotomy treated teeth becomes worse when furcal perforations occur because of the damage of the periodontal attachment apparatus. Immediate sealing of the perforation is therefore of paramount importance to ensure positive prognosis (33).

Over the time, there has been a continuous search for dental materials that present an ideal combination of good mechanical, physicochemical and biological properties. Concerning the treatment of periapical injuries this search has been even more incessant.

Cost has currently a great influence on material's selection. Mineral trioxide aggregate (MTA) has been shown to have good chemical and biological properties (37-43) and its behavior has been extensively investigated in several clinical applications (5, 44). The elevated cost of this product, however, presented a limiting factor for its wide clinical use.

In this study MTA was used as a gold standard since it is suitable sealant and highly biocompatible. Pro Root MTA has been proven to have less leakage and has produced a better response compared to other materials in a number of studies (15,45-46), so using it in this study as a highly effective perforation repair material to compare it with Portland cement to seal perforations in primary molars, in order to evaluate the possibility of substituting MTA with the less expensive Portland cement

Different leakage models have been used to assess the ability of materials to seal furcation perforations including fluid-infiltration, dye penetration, bacterial leakage models and dye extraction. The dye penetration techniques are the most frequently used methods (36,45,47), as they are easy to perform and do not require sophisticated materials. However, they possessed drawbacks like the smaller molecular size of most dye molecules than bacteria, which do not measure the actual volume absorbed by the sample but merely measure the deepest point reached by the dye (36). Despite of the drawbacks; **Torabinejad *et al.,*** (48) stated that a material that is able to prevent the penetration of small molecules (dye) should be able to prevent larger substances like bacteria and their byproducts.

Furthermore, the compatibility of the dye materials and the tested materials can adversely affect the microleakage results. The use of methylene blue in marginal sealing studies has been questioned, due to its incompatibility with alkaline substances which may induce discoloration of the dye. Since calcium oxide is one of the components found in MTA, when calcium oxide is mixed with water, it results in the formation of calcium hydroxide, with a subsequent increase in pH as demonstrated by **Duarte *et al.*** (49). Thus, discoloration of the surfaces stained by methylene blue may occur. Therefore, basic fuchsin solution was more appropriate for evaluating the sealing ability in this study (50). **Camps and Pashley** , showed that the dye extraction method yielded the same results as fluid infiltration while saving laboratory time (36).Using the dye extraction method **Hamad *et al.,*** (34) compared the sealing ability of gray and white MTA when used for furcation perforation repair and no significant difference was observed.

The results of this study revealed that the negative control group showed the lowest dye absorbance (0.134 ± 0.075) which is close to that of the (blank) nitric acid (0.141). This difference can be attributed to the greyish- white color of the primary molars, whereas the blank is colorless. On the other hand, the positive control group had the highest dye absorbance (0.631± 0.223) of all tested groups denoting the accuracy of the technique (34,50).

Furthermore, no significant difference between the dye absorbance values of MTA repair group (0.263± 0.051) and the PC repair group (0.278 ±

0.057**)**. This could be attributed to the fact that both materials had similar chemical formulations and physical properties (27), except for the bismuth oxide in MTA. Therefore, they may possess the same mechanisms of action in the promoting the healing process of the perforated site. These results are in agreement with **De-Deus *et al.*** (28) & **Charrier and Medioni** (50).

From the previous study it could be concluded that PC provides an effective seal of primary teeth furcal perforations and can be considered a more economic substitute for MTA as a repair material enhancing the prognosis of perforated primary teeth that would otherwise be extracted.

Recommendations:

- Studies to compare the solubility rate of MTA and Portland cement in relation to the normal root resorption rate during the shedding process.
- Studies to compare MTA and Portland cement as endodontic medicament in paediatric dentistry are necessary.
- Randomized clinical trials are to be conducted in order to determine the suitability of PC.

Corresponding author
Sherif B. El Tawil
Pediatric Dentistry Department, Faculty of Oral and Dental Medicine, Cairo University
drsherifbahgat@hotmail.com

References:

1- Barr ES, Flaitz CM, Hicks MJ(1991). A retrospective radiographic evaluation of primary molar pulpotomies. Pediatr Dent.; 13:4-9.
2- Naik S, Hegde AH(2005). Mineral trioxide aggregate as apulpotomy agent in primary molars: An in-vivo study. J Indian Soc Pedo Prev Dent.; 13-16.
3- Fuks AB(2002). Current concepts in vital primary pulp therapy. Eur J Paediatr Dent.;3:115-20.
4- Ranly D, García-Godoy F(2000). Current and potential pulp therapies for primary and young permanent teeth. J Dent.;28:153-61.
5- Torabinejad M, Chivian N(1999). Clinical application of mineral trioxide aggregate. J Endod.; 25(3):197–205.
6- Hatem A, Alhadainy H, Himel Van T, Memphis T(1993). Evaluation of the sealing ability of Amalgam, Cavit, Glass Ionomer Cement in the repair of furcation perforation. Oral Surg. Oral Med. Oral Pathol.; 75:362-366.
7- Salman M(1999). Histological evaluation of repare, using abioresorbable memberane beneath a resin-modified glass ionomer after mechanical furcation perforation in dog's teeth. J Endod.;25:181-186.
8- Chau JYM(1997). An *in vitro* study of furcation perforation repair calcium phosphate Cement. J Endod.; 23:588-592.
9- Himel VT, Alhadainy HA(1995). Effect of dentin preparation and acid etching on the sealing ability of glass ionomer and composite resin when used to repair furcation perforation over plaster of paris barriers. J Endod.; 21: 142-145.
10- Fuss Z, Abramovitz I, Metzger Z(2000). Sealing furcation perforations with silver glass Ionomer cement, An in vitro Evaluation. J Endod.; 26: 466-468.
11- Jantarat J, Stuart G, Harold H(1999): Effect of matrix placement on furcation perforation repair. J Endod.; 25: 192-196.
12- Mittal M, Chandra S, Chandra S(1999). An evaluation of plaster of paris barriers used under various materials to repair furcation perforation (*In vitro* study). J Endod.; 25: 385-388.
13- Torabinejad M, Rastegav AT, Kettering JO, Pittford TR(1995). Bacterial leakage of mineral trioxide as a root- end filling material. J Endod.; 21: 109-121.
14- Ruddle JG(2002). Nonsurgical endodontic retreatment.In: Cohn S, Burns RC, eds. Pathways of the pulp, 8th ed. St. Louis: Mosby Inc,:919.
15- Lee SJ, Monsef M, Torbinejad M(1993). Sealing ability of a mineral trioxide aggregate for repair of lateral root perforations. J Endod.;19: 541-544.
16- Osorio RM, Hefti A, Vertucci FJ, Shawley AL(1998). Cytotoxicity of endodontic materials. J Endod.; 24: 91-96.
17- Torbinejad M, Hong CU, Lee SJ, Monsef M, Pitt Ford TR(1995). Investigation of mineral trioxide aggregate for root- filling in dogs. J Endod.; 21:603-608.
18- Mc Cabe PS(2003). The clinical applications of mineral trioxide aggregate. J Ir Dent Assoc.; 49: 123-131.
19- Hardy I, Lieweher FR, Joyce AP, Agee K, Pashley DH(2004). Sealing ability of One- up Bond and MTA with and without a secondary seal as furcation perforation repair material. J Endod.; 30: 658-661.
20- Daoudi MF, Sauders WP(2002). *In vitro* evaluation of furcal perforation repair using mineral trioxide aggregate or resin modified glass ionomer cement with and without the use of the operating microscope. L Endod; 28: 512-515.
21- Nakata TT, Bae KS, Baumgartner JC(1998). Perforation repair comparing minera; trioxide aggregate and amalgam using an anaerobic bacterial leakage model. J Endod.; 184-186.
22- Hashem AA, Hassanien EE(2008). ProRoot MTA, MTA-Angelus and IRM used to repair furcation perforations: Sealability study. J Endod.; 34(1): 59-61.
23- Pitt Ford TR, Torabinjad M, McKendry DJ, Hong CU, Kariyawasam SP(1995). Use of mineral trioxide aggregate for repair of furcal perforations. Oral Surg Oral Med Oral Pathol Oral Radiol Endod.; 79: 756-763.
24- Roberts HW, Toth JM, Berzins DW, Charlton DG(2008). Mineral trioxide aggregate material use in endodontic treatment: a review of the literature. Dent Mater.; 24: 149-164.
25- Wucherpfenning AL (1999). Green DB Mineral trioxide vs Portland cement: two biocompatibile filling materials. J Endod.; 25:300- 308.
26- Estrela C, Bammann LL, Estrela CR, Silva RS, Pe´cora JD (2000). Antimicrobial and chemical study of

MTA, Portland cement, calcium hydroxide paste, Sealapex and Dycal. Braz Den J.; 11, 3–9.

27- De Deus G, Ximenes R, Gurgel-Filho ED, Plotkowski MC, Coutinho-Filho T (2005). Cytotoxicity of MTA and Portland cement on human ECV 204 endothelial cells. Int Endod J.;38:604-9

28- De-Deus G, Petruccelli E, Gurgel-Filho E, Coutinho-Fihlo T(2006). MTA versus Prtland cement as repair cement material for furcal perforations: a laboratory study using a polymicrobial leakage model. Int Endod J.; 39:293-298.

29- Saidon J, He J, Zhu Q, Safavi K, Spangberg LS (2003). Cell and tissue reactions to mineral trioxide aggregate and Portland cement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod.; 95, 483–499.

30- Menezes R, Bramante CM, Letra A, Carvalho VGG, Garcia RB(2004). Histologic evaluation of pulpotomies in dog using two types of mineral trioxide aggregate and white Portland cements as wound dressings. Oral Surg Oral Med Oral Pathol Oral Radiol Endod.;98:376-399.

31- Duarte MAH, Demarchi ACCO, Yamashita JC, Kuga MC, Fraga SC(2005). Arsenic release provided by MTA and Portland cement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod.;99:648-650.

32- Min KS, Kim HI, Park HJ, Pi SH, Hong CU, Kim EC(2007). Human pulp cells response to Portland cement *in vitro*. J Endod.; 33: 163-166.

33- Ahangari Z, Karami M(2006). Evaluation of the sealing ability of amalgam, MTA, Portland cement and Coltozol in the repair of furcal perforations. Iran Endod J.; 1(2): 60-64.

34- Hamad HA, Tordik PA, McClanahan SB(2006). Furcation perforation repair comparing gray and white MTA: a dye extraction study. J Endod.; 32:337-40.

35- De-Deus G, Reis C, Brandão C, Fidel S, Fidel RA(2007). The ability of Portland cement, MTA, and MTA Bio to prevent through-and-through fluid movementin repaired furcal perforations. *J Endod.*; 33(11):1374–1377.

36- Camps J, Pashley D(2003). Reliability of the dye penetration studies. J Endod.; 29:592–594.

37- Johnson BR(1999). Considerations in the selection of a root-end filling material. Oral Surg Oral Med Oral Pathol Oral Radiol Endod.;87: 398-404.

38- Aqrawabi J(2000). Sealing ability of amalgam, super EBA cement, and MTA when used as retrograde filling materials. Br Dent J.; 188: 266-268.

39- Andelin WE, Browning DF, Hsu G-Hong R, Roland DD, Torabinejad M (2002). Microleakage of resected MTA. J Endod.; 28: 573-574.

40- Pereira CL, Cenci MS, Demarco FF(2004). Sealing ability of MTA, Super-EBA, Vitremer and amalgam as root-end filling materials. Braz Oral Res.,;18: 317-321.

41- Scheerer SQ, Steiman R, Cohen J(2001). A comparative evaluation of three root-end filling materials: an in vitro leakage study using Prevotella nigrescens. J Endod.; 27:40-42.

42- Peters CI, Peters OA(2002). Occlusal loading of EBA and MTA root-end fillings in a computer-controlled masticator: a scanning electron microscopic study. Int Endod J.; 35:22-29.

43- Gondim E, Zaia AA, Gomes BPFA, Ferraz CCR, Teixeira FB, Souza-Filho FJ(2003). Investigation of the marginal adaptation of root-end filling materials in root-end cavities prepared with ultrasonic tips. Int Endod J.;36: 491-499.

44- Camilleri J, Montesin FE, Papaioannou S, McDonald F, Pitt Ford TR(2004). Biocompatibility of two commercial forms of mineral trioxide aggregate. Int Endod J.;37: 699-704.

45- Torabinejad M, Rastegar AF, Kettering JD, Pitt Ford TR(1995). Bacterial leakage of mineral trioxide aggregate as a root-end filling material. J Endod.; 21:109 –12.

46- Noetzel J, Ozer K, Reisshauer BH, Anil A, Rossler A, Neumann K, Kielbassa AM (2006). Tissue responses to an experimental calcium phosphate cement and mineral trioxide aggregate as materials for furcation perforation repair: a histological study in dogs. Clin Oral Invest.; 10: 77-83.

47- Souza EM, Pappen FG, Shemesh H, Bonanato-Estrela C, Bonetti-Fihlo I. Reliability of assessing dye penetration along canal fillings using methylene blue. Aust Endod J. 2009; 33: 1-6.

48- Torabinejad M, Watson TF, Pitt Ford TR(1993). Sealing ability of a mineral trioxide aggregate when used as root end filling material. J Endod.; 19: 591–595.

49- Duarte MAH, Demarchi AC, Yamashita JC, Kuga MC, Fraga SC(2003). pH and calcium ion release of 2 root end filling materials. Oral Surg Oral Med Oral Pathol Oral Radiol Endod.; 95(3):345-347..

50- Charrier M, Medioni E(2007). Microleakage of three filling materials for furcation perforation. Europ Cells and Mat.; 13(1): 9.

12/12/2011