Clinical and Radiographic Outcomes Of Pulpotomized Primary Molars Treated with White or Gray Mineral Trioxide Aggregate And Ferric Sulfate –Long Term Follow-Up

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Aim: *To compare the long term clinical and radiographic outcomes of pulpotomies in primary molars performed with white or gray Mineral Trioxide Aggregate (MTA) in combination with ferric sulfate (FS), when one package of MTA is used for multiple treatments.* ***Design:*** *Sixty eight children with 86 vital carious primary molars underwent pulpotomy with FS, and grey or white MTA. One package of MTA was used for 7-8 treatments. Clinical and radiographic evaluation was performed before and 6 to 47 months after treatment.* ***Results:*** *Success rates were similar for pulpotomies performed with white (60-teeth) and grey MTA (16 teeth) (p>0.05), and for those performed with the addition of FS to white or gray MTA when one package of MTA was used for multiple pulpotomies compared to one package of MTA alone.* ***Conclusion:*** *Gray and white MTA in conjunction with FS induce comparable clinical and radiographic success rate. The use of one package of MTA for multiple pulpotomies, combined with FS, is a cost-effective treatment.*

Keywords: *MTA, pulpotomy, ferric sulfate, children*

INTRODUCTION

Pulpotomy in primary dentition is a common therapeutic procedure for treating asymptomatic carious teeth with pulp exposure. Formocresol (FC), and more recently, ferric sulfate (FS), are the most commonly used agents in pulpotomy procedures in primary molars.[1] Though FC has been a popular pulpotomy medicament for the last 60 years, its systemic and toxic effects and carcinogenic potential have prompted a search for other medicaments for pulpotomy procedures.[2]

MTA is a powder with a pH value of 12.5. Its setting time, after exposure to moisture, is about 4 hours; and after several days its compressive strength reaches 70 Mpa, similar to that of intermediate restorative material (IRM). Its sealing ability was shown to be superior to that of amalgam or zinc oxide and eugenol.[3-4] The main advantages of MTA include its antimicrobial properties, biocompatibility to pulp tissue, maintenance of integrity with low inflammatory reaction, and induction of pulpal cells to secrete cytokines, which accelerate the formation of hard tissue barrier.[5-6] In an evidence-based assessment the radiographic success rate of pulpotomies performed with MTA was significantly higher than that performed with FS (Odd Ratio =4.69, CI= 1.70-12.95).[7] A common finding after pulpotomy with MTA is obliteration of the radicular pulp, indicating its biological effect on pulp tissue.[8-9] Nevertheless, one study reported a success rate of pulpotomies treated by MTA as low as 66.6% after 24 months, with dentinal bridge formation not observed in any of the treated teeth.[10] One of the most cited disadvantages, and the main reason that MTA was not adopted by the dental professional, is its high price. The price of one small packages of MTA (1 gr, ProRoot MTA, Densply, Tulsa, OK) is 88$, and the manufacturer recommends to use one original package for a single treatment.

In the last decade a white MTA was developed to eliminate the reflection of the gray color through the enamel surface, especially in the anterior teeth.[8,11] In an English literature search, only one study compared the clinical, radiographic, and histologic success rates of gray and white MTA as pulp dressing's materials in pulpotomized primary teeth. The results of this study showed that clinically, gray MTA appears to be superior to white MTA as a pulp dressing for pulpotomized primary teeth. Pulp canal obliteration was significantly more prevalent in teeth treated with gray MTA than in white MTA. Histologically, teeth treated with gray MTA demonstrated mainly pulp architecture nearest to normal pulp by preserving the odontoblastic layer and delicate fibrocellular matrix, however, teeth treated with white MTA showed a denser fibrotic pattern, with more isolated calcifications in the pulp tissue along with secondary dentin formation.[12]

FS induces hemostasis and the formation of a sealing membrane at the amputation wound by agglutinating the blood serum-proteins with the ferric and sulfate ions. This reaction minimizes the forma-

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Table 1. Pathological evidence developed during follow-up periods.

Number of children with failure of teeth	Type of tooth with failure	Age of child at treatment	Type of MTA	Period of follow-up in months	Type of Radiographic pathology	Type of clinical pathology
1	54	84 months	white	13	Inflammatory resorption	none
2	84	80 months	white	12	Radicular lesion	none
3	75	63 months	gray	36	Inflammatory resorption	none
4	84	92 months	white	26	Inflammatory resorption	none
5	75	46 months	gray	24	Inflammatory resorption	none
	85	47 months	gray	25	Inflammatory resorption	none
	55	51 months	white	19	Radicular lesion	fistula

tion of blood-clot, consequently decreasing infection, an inflammatory reaction, and the development of internal resorption in the residual radicular pulp.[13] In a systematic review that included 11 studies, the overall clinical and radiographic success rates of treatments with FS ranged from 78% to 100% (mean 91.6 +/- 8.15%) and from 42% to 97% (mean 73.5 +/- 18.40%), respectively. The main drawback of FS is that it hampers the development of a dental bridge, which protects the radicular pulp from future infection,[14] drawback that may be overcome by MTA.

Despite the advantages of FS in inducing immediate hemostasis, preventing blood clot formation and inducing a membrane-seal, and that of MTA in inducing dental bridge formation, no study has evaluated the success rate of pulpotomies performed by combination of FS and gray or white MTA. The aims of the present study were therefore twofold: I. To compare the clinical and radiographic success rates of gray and white MTA, when one package of MTA is used for multiple patients. II. To evaluate the success rate of pulpotomy in primary molars performed with FS and white or gray MTA.

MATERIALS AND METHOD

The study population included children who received routine dental treatment at one pediatric dental clinic, and were treated by the same certified pediatric dentist (MA). A structured form was designed to collect all demographic and dental variables, including patient age and gender, type of tooth treated, type of complications – radiographic or clinical, dates of follow-up including radiographic follow-up. The Ethics Committee of Tel Aviv University approved the study.

Primary molars for which pulp was exposed during removal of a deep caries lesion, but without any other clinical or radiographic pathologic signs, were included. Before treatment, the teeth were anesthetized by C-CLAD (infiltration, intra-ligamental, or mandibular block).[15] Immediately after local anesthesia delivery, a rubber dam was applied. The caries was removed from the periphery to the center of the caries lesion. Immediately after complete removal of carious tissue, all the burs were replaced by new sterile burs. The roof of the pulp chamber and the pulp tissue was removed by a sterile high speed diamond bur. Hemostasis was promptly achieved by pushing a sterile cotton pellet dipped with ferric sulfate against the orifices of the radicular pulp. MTA powder (white or gray) was then mixed with sterile water according to manufacture instructions, and the paste applied to the top of the radicular pulp by a sterile cotton pellet. The rest of the pulp chamber was filled by IRM, and the tooth was restored immediately, at the same appointment, with a preformed crown. The opened package of the MTA was then sealed by a paper-clip and by a sterilization wrap. Each package of MTA powder was used until finished (7-8 treatments). Gray or white MTA were used alternately until the packages were finished. However, since gray MTA was not available after the first year of the study period, white MTA was used for the remaining teeth.

Inclusion criteria were primary molars with pulp exposure during removal of a deep caries lesion, but without any other clinical or radiographic pathologic signs. In addition, the teeth had at least 6 months follow-up.

Exclusion criteria were teeth with a history of spontaneous pain, pain evoked at night, sensitivity to percussion or touch, gingival swelling, the presence of a sinus tract, pathological mobility, advanced caries lesion that cannot be restored by a crown, or extensive bleeding at the pulpotomy procedure. In addition, teeth were excluded with radiographic evidence of physiologic root resorption exceeding half of the root length, external or internal inflammatory root resorption, or the presence of periapical radiolucency or pulp obliteration.

A clinical examination was performed at every routine periodic examination of the child in the dental office. Notes were attached to files of participating patients stating involvement in the study. Evidence of swelling, presence of a sinus tract, pathological mobility, spontaneous pain or pain evoked at night or sensitivity to percussion or to touch, were documented on follow-up forms. Periapical radiographs were performed in conjunction with periodic bitewings examination, in theses high risk population, on a larger film to include the roots of the treated tooth without exposing the patient to additional radiation.

Table 2. Distribution and timing of radiographic findings in primary molars treated by white or gray MTA in combination with FS

Follow-up in months	Number of teeth (%) without any radiographic findings			Number of teeth (%) with obliteration			Number of teeth (%) with dentin bridge			Number of teeth (%) with radiological failure			Total teeth
	White MTA	Grey MTA	Total Teeth	White MTA	Grey MTA	Total	White MTA	Grey MTA	Total	White MTA	Grey MTA	Total	
6-11	46 76.7%	11 68.8%	57 75.0%	8 13.3%	2 12.5%	10 13.2%	3 5.0%	0 0.0%	3 3.9%	3 5.0%	3 18.8%	6 7.9%	76 100.0%
12-17	25 61.0%	6 40.0%	31 55.4%	9 22.0%	5 33.3%	14 25.0%	4 8%	1 6.7%	5 8.9%	3 7.3%	3 20.0%	6 10.7%	56 100.0%
18-23	18 64.3%	6 46.2%	24 58.5%	5 17.9%	3 23.1%	8 19.5%	4 14.3%	1 7.7%	5 12.2%	1 3.6%	3 23.1%	4 9.8%	41 100.0%
24-29	14 70.0%	5 45.5%	19 61.3%	4 20.0%	2 18.2%	6 19.4%	1 5.0%	1 9.1%	2 6.5%	1 5.0%	3 27.3%	4 12.9%	31 100.0%
30-35	6 66.7%	3 42.9%	9 56.3%	3 33.3%	1 14.3%	4 25.0%	0 0.0%	1 14.3%	1 6.3%	0 0.0%	2 28.6%	2 12.5%	16 100.0%
36-41	4 57.1%	1 20.0%	5 41.7%	2 28.6%	2 40.0%	4 33.3%	1 14.3%	1 20.0%	2 16.7%	0 0.0%	1 20.0%	1 8.3%	12 100.0%
42-47	3 60.0%	1 25.0%	4 44.4%	2 40.0%	2 50.0%	4 44.4%	0 0.0%	1 25.0%	1 11.1%	0 0.0%	0 0.0%	0 0.0%	9 100.0%

Clinical success was defined when the treated tooth was not sensitive to percussion, without mobility, and without swelling or sensitivity in the attached gingival. Radiographic success was defined when there were no signs of internal or external inflammatory root resorption, nor any furcation or periapical rarefactions. Obliteration of root canal and formation of a dentinal bridge was not regarded as failure.

Statistical analysis

The student t-test and chi-square test were used to calculate the significant differences between continuous and nominal variables, respectively. A standard statistical package (SPSS 10.0, Chicago, IL) was used to analyze the results. Univariate analysis was performed by the Anova test, and correlation by Fisher's Exact test.

RESULTS

The study population consisted of 68 children (28 boys, 41.2%), mean age of 70.3 ± 21.2 months (median 68 months) who received pulpotomy in 86 primary molars during routine dental treatment by one certified pediatric dentist. Sixty primary molars were treated with white MTA and 16 with gray MTA. After 6-11, 12-17, 18-23, 24-29, 30-35, 36-41, 42-47 months, 68, 48, 32, 23, 14, 10, and 7 children, respectively arrived for follow-up examinations. Clinical and radiologic follow-up examinations were performed on 76 teeth. In 10 additional primary molars, only clinical follow-up examinations were available (Tables 1-2).

Following 6-11 months, 86 primary molars (68 children) were available for clinical evaluation, 76 (63 children) of them also for radiographic evaluation. The clinical success rate was 100%, and the radiographic success rate 92.1% (70 teeth in 60 children). Of the treated molars for which there were also radiographic evaluations, 13.2% (10 molars in 7 children) showed root-canal obliteration and 4% (3 molars in 3 children) dentinal bridge formation. In 7.9% (6 molars in 4 children) of the molars with radiographic evaluations, pathological signs were observed.

Clinical and radiographic outcomes at 12-17 months follow-up (Tables 1-2)

Following 12-17 months, 62 primary molars (48 children) were available for clinical evaluation, 56 (44 children) of them also for radiographic evaluation. The clinical success rate was 100%, and the radiographic success rate 89.3% (50 teeth in 42 children). Of the treated molars for which there were also radiographic evaluations, 25% (14 teeth in 11 children) showed root-canal obliteration and 8.9% (5 molars in 4 children) dentinal bridge. In 10.7% (6 molars in 4 children) of the molars with radiographic evaluation, pathological signs were observed.

Clinical and radiographic outcomes at 18-23 months follow-up (Tables 1-2)

Following 18-23 months, 44 primary molars (32 children) were available for clinical evaluation, 41 (93.1%) of them also for radiographic evaluation. The clinical success rate was 97.7% (43 molars in 32 children). One molar showed development of a sinus tract. The radiographic success rate was 90.2% (37 molars in 30 children). Of the molars for which there were also radiographic evaluations, 19.5% (8 molars in 7 children) showed root-canal obliteration and 12.2% (five molars in 5 children) dentinal bridge. In 9.8% (4 molars in 2 children) of the molars with radiographic evaluation, pathological signs were observed.

Clinical and radiographic outcomes at 24-29 months follow-up (Tables 1-2)

Following 24-29 months, 34 molars (23 children) were available for clinical evaluation, 31 (91.2%) of them also for radiographic evaluation. The clinical success rate was 100%. Radiographic success was observed in 27 molars (87.1% in 22 children); 19.4% (6 teeth in 5 children) had root-canal obliteration and 6.5% (2 molars in 2 children) dentinal bridge. In 12.9% (4 molars in 2 children) of the molars with radiographic evaluation, pathological signs were observed.

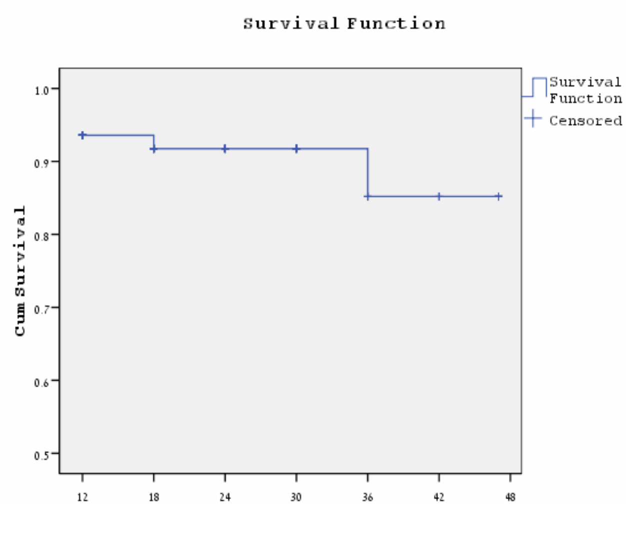

Figure 1 . Survival rate (Kaplan-Meier survival rate plot) of teeth treated during 47 months follow-up

Clinical and radiographic outcomes at 30-35 months follow-up (Tables 1-2)

Following 30-35 months, 18 molars (12 children) were available for clinical evaluation, 16 (88.9%) molars of them also for radiographic evaluation. The clinical success rate was 100%. Radiographic success was observed in 14 molars (87.5% in 10 children); 25% (4 teeth in 4 children) had root-canal obliteration and 6.3% (1 molars in 1 children) dentinal bridge. In 12.5% (2 molars in 2 children) of the molars with radiographic evaluation, pathological signs were observed.

Clinical and radiographic outcomes at 36-41 months follow-up (Table 1-2)

Following 36-41 months, 12 molars (9 children) were available for clinical and radiographic evaluation (100%). The clinical success rate was 100%. Radiographic success was 91.7% (11 molars in 9 children). In 4 teeth (33.3%, 4 children) there was root-canal obliteration and in 2 molars (16.7%, 2 children) dentinal bridge. In 8.3% of the molars with radiographic evaluation (1 molar in 1 child), pathological signs were observed. We note that this pathologic observation was already accounted for in the previous follow up.

Clinical and radiographic outcomes at 42-47 months follow-up (Table 1-2)

Following 42-47 months, 9 molars (7 children) (100%) were available for clinical and radiographic evaluation. Clinical and radiographic success rates were 100% (9 molars in 7 children). In 4 teeth (44.4%, 4 children) there was an evidence of root-canal obliteration and in 1 molar (11.1% in 1 child) dentinal bridge. No pathological evidence was observed.

During 47 months of follow-up, a total of 5 children with seven treated molars developed pathological signs that were diagnosed 6 to 17 months after treatment. The mean age of these children was 78 months. One of these children had failures in three of his teeth (2 molars with internal resorption and one with radicular radiolucency in conjunction with a sinus tract). Clinical sign of failure, presenting as a sinus tract was found in only one treated molar. This molar had also radiographic evidence of periapical lesions. Radiographic failures were expressed in 5 teeth by inflammatory resorption and in the other two molars by presence of periapical lesions.

No statistical difference was found in the success rate of molars treated by gray or white MTA ($p<0.005$, Table 2), or between first and second primary molars ($p<0.005$, Table 1). In contrast, the success rate of pulpotomy in maxillary molars was higher by 9.5% and 9% than that of mandibular molars, after 12 and 30 months, respectively, $p<0.05$.

Kaplan-Meier survival rate plot- Figure 1

Survival rate of teeth treated by gray or white MTA was 0.9 and 0.84 after 36 and 47 months, respectively.

DISCUSSION

In this study, the radiologic and clinical success rates of pulpotomies treated by gray or white MTA was similar. Further, the use of one package of MTA for up to 8 treatments did not decrease effectiveness. The radiographic success rates of pulpotomy performed with FS added to gray or white MTA after 12, 16, 24, 30, 36, 42, and 48 months were 92.1%, 89.3%, 90.2%, 87%, 87.5%, 100%, and 100% respectively; the clinical success rate ranged from 97.8-100% during the follow-up period. The survival rate of the treated teeth was 0.9 after 36 months and 0.87 after 47 months. This rate is higher by 70% (0.53 after 24 months) than previously publish data of molars treated with FS alone.[5] Accordingly, these results show that addition of FS to white or gray MTA, even when one package is used for multiple treatments, increases the success rate as compared to treatment by FS alone. It seems that the combination of the two medicaments does not interfere with the biological effect of the MTA, thus exploiting the advantage of FS in creating hemostasis and in preventing the formation of blood clot during pulpotomy.

MTA seems to be an ideal medicament for pulpotomy in primary teeth, except for its high price, which is particularly elevated due to the recommendation to use each package for one patient only. However, Soluçoas Odontológicas (Londrina, PR, Brazil) markets the MTA-Angelus in a sealed bottle and allows its use for multiple treatments.[16-17] The main differences in the components of these two products are: ProRoot MTA consists of 75% Portland cement, 20% bismuth oxide, and 5% calcium sulfate dehydrate, while MTA-Angelus contains 80% Portland cement and 20% bismuth oxide, with no addition of calcium sulfate. Calcium sulfate was eliminated in an attempt to reduce setting time (2 hours for ProRoot MTA and 10 minutes for MTA-Angelus).[17] In the present study, one package of 1 gr of MTA (ProRoot, Densply) was used for up to 8 treatments, and the package was re-sealed between treatments. In addition, the MTA was added to FS.

A limitation of this study is that, since not all patients arrived routinely every 6 months for periodic examinations, the success rate at each period was calculated solely from the patients who arrived during each follow-up period. Most of the failures (6 out of 7) were diagnosed during the first follow-up period, 6-11 months after treatment; and only one during the second period, after 12-18 months. This may indicate that most failures developed within 18 months following the treatment. Failure of treatment may result from histological inflammation that could not be diagnosed clinically or from biological or immunological responses of patients to the medicaments applied. The fact that three of 7 failures occurred in the same patient supports the latter, and suggests individual effects to the medicaments.

CONCLUSION

The present study showed similar success rates of pulpotomy performed with FS when MTA was used for multiple pulpotomies, compared to when a package of MTA was used for one patient only, as in previously publish studies, and as in the manufacturer's recommendations. This finding may significantly decrease expenses of performing pulpotomy with MTA, and remove obstacles from using MTA in routine pediatric practice.

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