Comparison of Mineral Trioxide Aggregate and Formocresol as Pulp-capping Agents in Pulpotomized Primary Teeth

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Abstract

Purpose: The aim of this study was to use clinical, radiographic, and histologic examinations to compare the relative success of gray mineral trioxide aggregate (MTA), white MTA, and formocresol as pulp dressings in pulpotomized primary teeth.

Methods: Twenty-four children, each with at least 3 primary molars requiring pulpotomy, were selected for this study's clinical and radiographic portion. An additional 15 carious primary teeth planned for serial extraction were selected for this study's histologic portion. All selected teeth were evenly divided into 3 test groups and treated with pulpotomies. Gray MTA was used as the pulp dressing for one third of the teeth, white MTA was the dressing for one third, and the remaining one third were treated with formocresol. The treated teeth selected for the clinical and radiographic evaluations were monitored periodically for 12 months. The treated teeth selected for histologic study were monitored periodically and extracted 6 months postoperatively.

Results: Four children with 12 pulpotomized teeth failed to return for any follow-up evaluations in the clinical and radiographic study. Of the remaining 60 teeth in 20 patients, 1 tooth (gray MTA) exfoliated normally and 6 teeth (4 white MTA and 2 formocresol) failed due to abscesses. The remaining 53 teeth appeared to be clinically and radiographically successful 12 months postoperatively. Pulp canal obliteration was a radiographic finding in 11 teeth treated with gray MTA and 1 tooth treated with white MTA. In the histologic study, both types of MTA successfully induced thick dentin bridge formation at the amputation sites, while formocresol induced thin, poorly calcified dentin. Teeth treated with gray MTA demonstrated pulp architecture nearest to normal pulp by preserving the odontoblastic layer and delicate fibrocellular matrix, yet few inflammatory cells or isolated calcified bodies were seen. Teeth treated with white MTA showed a denser fibrotic pattern, with more isolated calcifications in the pulp tissue along with secondary dentin formation.

Conclusions: Gray MTA appears to be superior to white MTA and formocresol as a pulp dressing for pulpotomized primary teeth. (*Pediatr Dent.* 2004;26:302-309)

KEYWORDS: PULPOTOMY, PRIMARY TEETH, MINERAL TRIOXIDE AGGREGATE, MTA

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Pulpotomy is one of the most frequently used treatments for retaining cariously involved primary molars that would otherwise be extracted.[1,2]

Formocresol has been a popular pulpotomy medicament for many years. Concerns have been expressed about formocresol pulpotomy because of observed: (1) pulpal responses with inflammation and necrosis;[3] (2) cytotoxicity;[4] (3) systemic disturbances;[5] (4) mutagenic and carcinogenic potential;[6] and (5) immunologic responses.[7] Different alternatives have been proposed to maintain partial pulp vitality.[8-15]

Table 1. Clinical Assessment of the 3 Groups at Different Evaluation Periods

Material		Evaluation periods				Freidman ANOVA	
		1 month	3 months	6 months	12 months		
		No. (%)	No. (%)	No.(%)	No. (%)	X^2	*P*
Gray MTA	Success	20 (100)	20 (100)	19* (100)	19* (100)		
	Failure	0 (—)	0 (—)	0 (—)	0 (—)	0	1
White MTA	Success	20 (100)	19 (95)	19 (95)	16 (80)		
	Failure	0 (—)	1 (5)	1† (5)	4†‡ (20)	1.08	.7819
Formocresol	Success	20 (100)	20 (100)	20 (100)	18 (90)		
	Failure	0 (—)	0 (—)	0 (—)	2 (—)	0.360	.9484
Kruskull Wallis	X^2	0	2	1.93	4.19		
	P	1	.3679	.3772	5.1228		

*One tooth exfoliated normally between the 3-month and 6-month evaluations.
†One tooth failure observed at the 3-month evaluation.
‡Mann-Whitney test showed significant difference between gray and white MTA at z=2.0312 (P=.0422).

The US Food and Drug Administration approved mineral trioxide aggregate (MTA) in 1998 as a therapeutic endodontic material for humans.[16-18] Torabinejad et al,[19,20] Bates et al,[21] and Fischer et al[22] evaluated the sealing ability of MTA in root canals. MTA was determined to be at least equal and often superior to amalgam, intermediate restorative material (IRM) and super-ethoxybenzoic acid (EBA).

In histologic studies by Pitt Ford et al[23] and Torabinejad et al,[24] root perforation repair using MTA showed biocompatibility and very little inflammation, even when the material was extruded beyond the perforation site.

Koh et al[25] studied human osteoblasts in vitro and found that MTA stimulated the release of cytokines and production of interlukin. Holland et al[26] showed that MTA induced hard tissue formation.

Schwartz et al[17] and Torabinejad and Chivian in 1999[27] presented cases in which MTA was used to manage many clinical problems. These included successful pulp caps, apexifixations, root perforation repairs (surgical and nonsurgical), and root-end fillings. In all cases, MTA allowed bone healing and elimination of clinical symptoms.

Eidelman et al[28] compared MTA's effects to those of formocresol as pulp dressing agents in pulpotomized primary molars with carious pulp exposures. MTA showed very high clinical and radiographic success rates as a pulpotomy dressing in primary teeth. The authors suggest that MTA may be a suitable replacement for formocresol for primary teeth pulpotomies.

Schmitt et al[29] reported that Tulsa Dental provides MTA as ProRoot. The material can be placed in the tooth with the Tulsa carrier, an amalgam carrier, Messing gun, or a hand instrument.

More recently, White ProRoot (white MTA) root canal repair material was introduced as an esthetic improvement over the original material (gray MTA) for placement in anterior teeth. The major components of white MTA are tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium sulfate dehydrate, and bismuth oxide.[30]

Fuks[31] discussed the biologic validity of various vital pulp treatments for primary teeth. She stated, "...indirect pulp treatment can be an acceptable procedure for primary teeth with reversible pulp inflammation, provided that this diagnosis is based on a good history, a proper clinical and radiographic examination, and the tooth had been sealed with a leakage-free restoration." She also noted that several articles have reported success of direct pulp capping of properly selected primary teeth. She suggested that ferric sulfate may replace formocresol as the pulp dressing for pulpotomized primary teeth. She also noted that even better results have been observed recently using MTA as the pulpotomy dressing. MTA not only yields good success rates but it also did not induce internal root resorption, a finding seen with both ferric sulfate and formocresol treated teeth.

The goals of this investigation were to:

1. compare the clinical and radiographic results of gray vs white MTA pulpotomies performed on vital human primary molars;
2. compare the clinical and radiographic results of MTA (gray and white) with formocresol pulpotomies on vital human primary molars;
3. compare the histologic pulpal responses of gray vs white MTA pulpotomies performed on vital human primary molars;
4. compare the histologic pulpal responses of MTA (gray and white) with formocresol pulpotomies on vital human primary molars.

Methods

Twenty-four children were selected for clinical and radiographic study from patients attending the clinic of the Pediatric Dentistry Department, Faculty of Dentistry, Alexandria University,

Table 2. Radiographic Findings of the 3 Groups After 12 Months

Material	Normal pulp (%)	Pulp canal obliteration (%)	Radicular bone destruction (%)	Total teeth examined (%)
Gray MTA	8 (42)	11 (58)	0 (0)	19* (95)
White MTA	15 (75)	1 (5)	4† (20)	20† (100)
Formocresol	18 (90)	0 (0)	2 (10)	20 (100)

*One tooth exfoliated normally between the 3-month and 6-month evaluations.
†One tooth failure observed at the 3-month evaluation.

Alexandria, Egypt. Each child had at least 3 primary molars with nearly equal carious involvement that required pulpotomy. Their ages ranged between 4 to 8 years, with a mean age of 6.1 years. The children were healthy and cooperative. Full detailed treatment plans were explained to the parents and children. Written consents for treatment were obtained from the children's parents prior to the clinical procedures.

The criteria for tooth selection in this study were:

1. primary molars with vital carious pulp exposures that bled upon entering the pulp chambers;
2. no clinical symptoms or evidence of pulp degeneration, such as pain on percussion, history of swelling, or sinus tracts;
3. no radiographic signs of internal or external resorption and no furcation radiolucency;
4. teeth would be restorable with posterior stainless steel crowns.

Preoperative periapical radiographs of the teeth considered for treatment in the study were made using the XCP extension cone paralleling technique. The selected teeth were randomly assigned and divided into 3 test groups according to the pulp dressings used. Group I included 24 teeth treated with gray MTA. Group II included 24 teeth treated with white MTA. Group III included 24 teeth treated with formocresol (control group). The treatments were distributed randomly to each of 3 teeth so that each child would receive 3 different treatments.

After administration of local anesthesia, the assigned molars were isolated with a rubber dam. After caries removal, coronal access was performed with a no. 330 high-speed bur with water spray to expose the pulp chamber. A spoon excavator was used for coronal pulp amputation, and water-moistened cotton pellet was used to achieve hemostasis. In test groups I and II, the pulp stumps were covered with gray or white MTA paste formed by mixing the MTA powder with sterile saline in a 3:1 powder/saline ratio, according to the manufacturer recommendations. In test group III, a cotton pellet moistened with formocresol was placed for 5 minutes on the pulp stumps and then the pulps were covered with zinc oxide and eugenol cement.

In all groups, a layer of IRM was placed over the pulp dressings prior to restoring each tooth with a stainless steel crown. The same operator provided these treatments to all 24 patients in this portion of the study.

The children were recalled for clinical and radiographic evaluations after 1, 3, 6, and 12 months. Two examiners, who were blinded to the treatment type, evaluated the teeth clinically and radiographically. Teeth were scored as clinical successes if they had no: (1) pain symptoms; (2) tenderness to percussion; (3) swelling; (4) fistulation; or (5) pathologic mobility. Teeth were scored as radiographic successes if they showed no evidence of: (1) radicular radiolucency; (2) internal or external root resorption; or (3) periodontal ligament space widening. Radiographic evidence of pulp canal obliteration was noted, but it was not regarded as a failure.

Data analysis

Clinical treatment outcomes and radiographic findings were submitted for statistical analysis. Statistical percentage was used to summarize categorical data. The Friedman ANOVA test was used to detect the statistical differences for each medicament at the different follow-up periods.

The differences among the 3 medicaments at each follow-up period were determined by the Kruskal Wallis test. The Mann-Whitney test was conducted to compare differences in the 3 groups at the final observation period.

Histologic study

An additional 15 carious primary teeth planned for serial extraction were selected for histologic study. The teeth were divided into 3 test groups of 5 teeth each, according to the pulp dressing to be used. They were then treated with the same 3 pulpotomy procedures previously described. All 15 teeth were evaluated clinically and radiographically at 1, 3, and 6 months. The teeth were extracted after 6 months to assess the pulps' histologic responses to the 3 different pulp dressings.

The extracted teeth were fixed in neutral formalin, after sealing the apical foraminae, and decalcified in 5% trichloroacetic-acid. Buccolingual sections were processed and prepared for examination by light microscopy, using either hematoxylin and eosin or trichrome stain. Each specimen was observed for dentin bridge formation, odontoblastic layer integrity, pulp inflammation, pulp calcification, and pulp vitality.

Results

Twenty children, with a total of 60 pulpotomized primary molars, were available for follow-up evaluations. Four children, with 12 pulpotomized molars, failed to return for evaluations and were excluded from the study.

All 60 teeth were scored as clinical and radiographic successes at the 1-month postoperative evaluation. At the 3-month evaluations, 1 tooth from the white MTA group

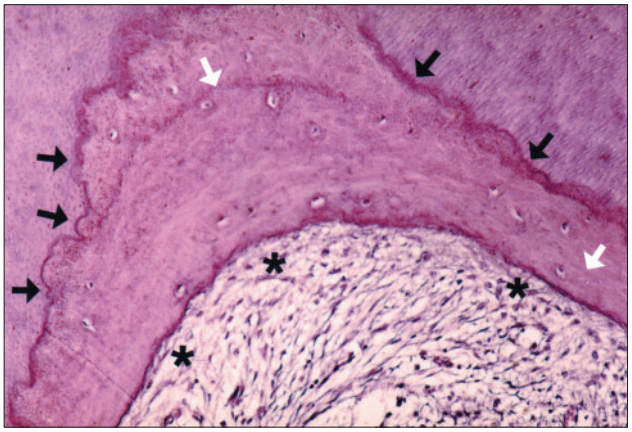

Figure 1. This photomicrograph of a section of tooth treated with gray MTA shows the deposition of secondary dentin bridging the pulp tissue with reversal lines (black arrows) and resting lines (white arrows), a regularly arranged odontoblastic cell layer (above the asterisks), and normal pulp architectural pattern with few inflammatory cells (hematoxylin-eosin stain, ×200 magnification).

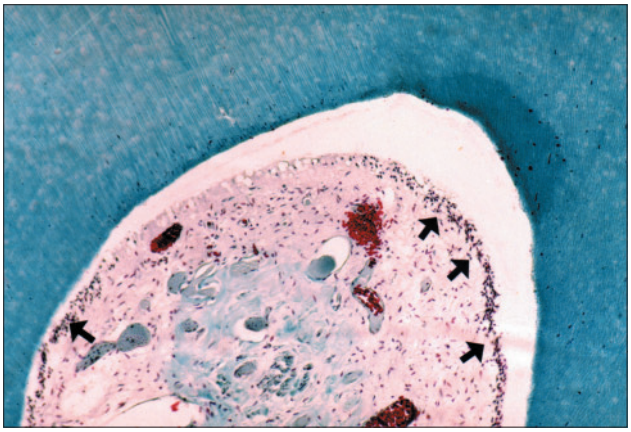

Figure 2. This photomicrograph tooth section, treated with gray MTA, reveals multiple small globular areas of pulp calcifications dispersed within the pulp tissue, along with a few hyperemic blood vessels and regularly arranged odontoblastic layer (arrows; trichrome stain ×100 magnification).

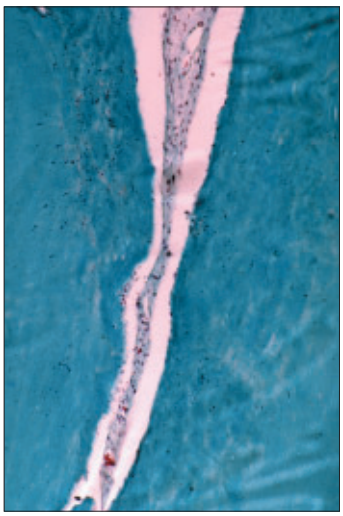

Figure 3. This view, made from a tooth treated with gray MTA, shows secondary dentin formation along the root canal and normal pulp architecture (trichrome stain ×200 magnification).

was scored as both a clinical and radiographic failure, due to an abscess, and the tooth was extracted. The remaining 59 teeth were scored as clinical and radiographic successes 3 months postoperatively. At the 6-month evaluation, 1 tooth from the gray MTA group was missing due to normal exfoliation and the remaining 58 teeth were scored as clinical and radiographic successes.

At the 12-month evaluation, the 19 teeth in the gray MTA group were all scored as clinical and radiographic successes. In the white MTA group, 3 teeth were scored as clinical and radiographic failures. The remaining 16 teeth in the white MTA group were determined to be clinical and radiographic successes. Two teeth in the formocresol group were scored as clinical and radiographic failures. Tables 1 and 2, respectively, summarize the study's clinical and radiographic results.

Using the Friedman ANOVA test, there were no significant differences after the 1-, 3-, 6-, and 12-month evaluation periods for the gray MTA group at $X^2=0$, $P=1$. For the white MTA group, there were no significant differences between the 12-month evaluation and the 1-, 3-, and 6-month evaluation, where $X^2=1.08$, $P=.7819$.

Using the Mann-Whitney test at 12 months postoperatively, however, there was a significant difference between the white MTA Group and the gray MTA group at $z=2.0312$, $P=.0422$. There was no significant difference between the white MTA group and formocresol group at $z=0.8745$, $P=.3819$.

The Kruskal Wallis test demonstrated no statistical differences between the formocresol group and gray MTA group or the white MTA group after 1-, 3-, 6-, and 12-month evaluations.

Histologic observations

Gray MTA group

Deposition of thick layers of secondary dentin was observed successfully bridging the pulp tissues at the amputation sites. Reversal and resting lines were seen in the dentin nearest the pulp. The normal pulpal architectural patterns were largely preserved and showed minor increases in fine collagen fibers and very few inflammatory cells. The odontoblastic layer was also preserved, showing a continuous regular arrangement at the pulp-dentin junction in all specimens (Figure 1). Pulp calcifications were seen in a few sections, either in the form of large masses within the pulp tissue near to and communicating with the newly formed secondary dentin or as small globular areas of calcifications dispersed within the pulp tissue (Figure 2). Dilated engorged blood vessels were rarely encountered. Higher magnification of the pulp tissues revealed their fibrocellular nature and continuous odontoblastic layers deposited at the secondary dentin interfaces.

Increased secondary dentin formation nearly obliterating the root canals was observed in some areas. The canals maintained their normal pulpal architecture (Figure 3).

White MTA group

Again, successful deposition of secondary dentin resulting in bridge formation across the pulp tissue near the amputation site was the dominant picture from all teeth in this group. The secondary dentin deposits were excessive, however, and nearly

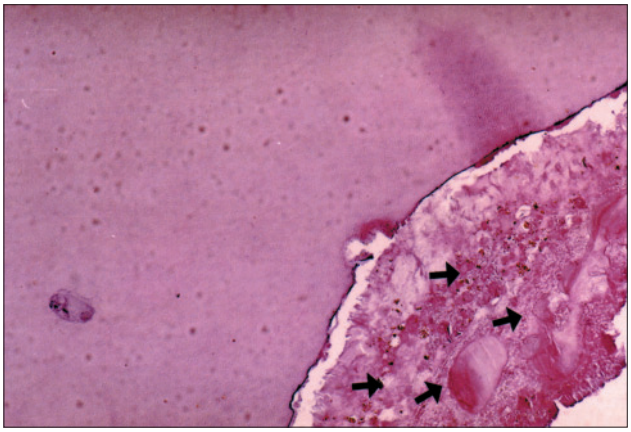

Figure 4. This photomicrograph, made from a tooth treated with white MTA, shows a thicker layer of secondary dentin bridging the pulp as well as multiple small pulp calcifications (arrows) throughout and nearly obliterating the pulp tissue (hematoxylin-eosin stain ×200 magnification).

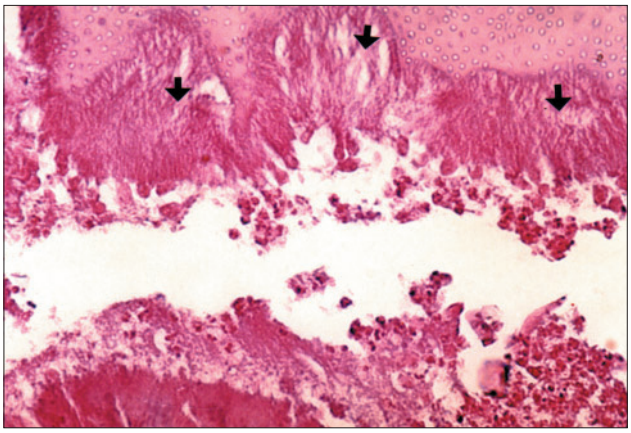

Figure 5. This section from a tooth treated with white MTA demonstrates a more fibrillar secondary dentin near the pulp (arrows). Discontinuity of the odontoblastic cell layer, areas of partial necrosis, and the presence of some inflammatory cells are also seen (hematoxylin-eosin stain ×400 magnification).

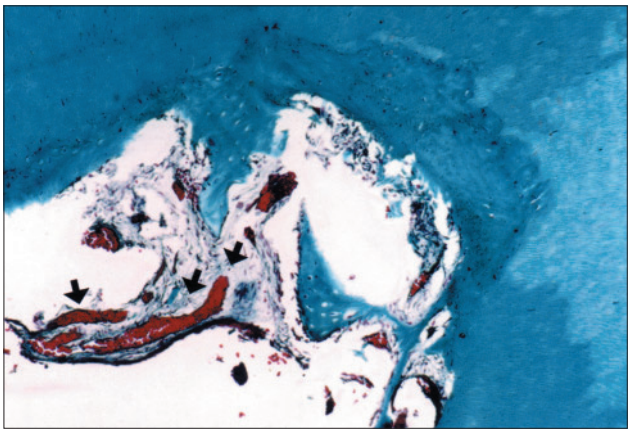

Figure 6. This photomicrograph of a section of a tooth treated with white MTA shows small areas of pulp calcifications communicating with deposited secondary dentin. Note the dilated blood vessels (arrows; trichrome stain ×100 magnification).

obliterated the pulp chambers or completely bridged them (Figure 4). The pulp responses showed varied architectural patterns, but mainly favored a fibrotic pattern with multiple pulp calcifications. The most common histologic picture showed fibrillar secondary dentin together with irregular odontoblastic layers, inflammatory cells, and pulp homogeneity with areas of partial necrosis (Figure 5).

This subgroup's pulp calcifications varied greatly in size from:

1. large calcifications;
2. smaller areas of multiple calcifications lying near to the dentin surface and very near to each other, dispersed in pulp tissue and nearly obliterating it; or
3. areas of small solitary calcifications communicating with the deposited secondary dentin.

Higher magnification of the pulp tissue revealed a fibrotic architecture with some loss of continuity of the odontoblastic layer and a few dilated engorged blood vessels (Figure 6).

The root canals also showed secondary dentin deposition, while dilated blood vessels and a few areas of increased fibrosis were seen in the pulp tissues (Figure 7).

Formocresol group

Depositions of poorly calcified secondary dentin bridging the pulp tissues were seen. The dispersed pulps were almost completely necrotic with islands of inflammatory cells. The specimens showed little evidence of odontoblastic cell layers present (Figure 8).

Discussion

Special care was taken in choosing teeth for this study to assure similarity in the amount of caries involvement and, presumably, pulpal inflammation. Formocresol was selected as the control pulpotomy dressing because it is still considered by many to be the standard therapeutic agent for the pulpotomy procedure in primary teeth.

In the clinical and radiographic study, the primary molars treated with gray MTA showed no adverse clinical or radiographic changes after 12 months. The primary molars treated with white MTA showed 4 cases of failure during the same 12-month period. The primary molars treated with formocresol showed 2 cases of failure at their 12-month evaluation. These gray MTA and formocresol findings are quite similar to those of Eidelman et al,[28] but their study did not include a white MTA treatment group. This study's white MTA group showed a somewhat lower clinical and radiographic success rate of 80% when compared with the 90% and 100% success rates of the formocresol and gray MTA groups, respectively.

Perhaps the minor difference in composition between gray and white MTA groups accounts for the differences in the pulpotomy success rates of this study's 2 test groups. Gray MTA contains tetracalcium aluminoferrite, while this substance is absent in white MTA. The clinical and radiographic success rates of the formocresol group in this study

are similar to the success rates observed by Fuks et al[32] in pulpotomized primary teeth treated with dilute formocresol.

Because the teeth used in this histologic study were planned for serial extraction, they needed to be removed 6 months after treatment. The histologic features observed at that time were used as an indicator of the relative success of each capping material. Under the microscope, the white MTA specimens showed dentin bridge formation, as did the gray MTA specimens, but the pulp tissue of many of the white MTA specimens also revealed more inflammatory cells and a few areas of necrosis. It was also observed in this study that the gray MTA's effects on amputated pulpal tissue seem to suggest that the material preserves the pulp tissue and promotes the regeneration of both soft and hard tissues. The nearly normal pulpal architecture, intact and continuous odontoblastic layer, and reparative dentin bridging observed in this group indicate the material's biocompatibility and regeneration ability. These findings are similar to several previous in vivo studies with MTA.[19,24,33]

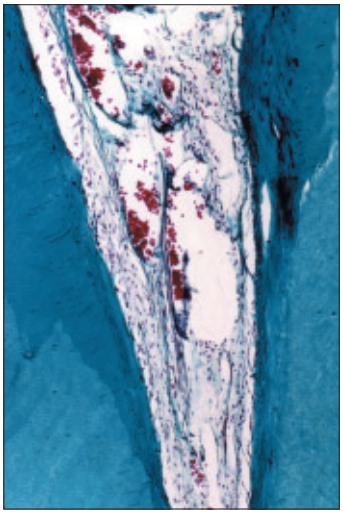

Figure 7. This view, made from a tooth treated with white MTA, demonstrates secondary dentin formation along the root canal. Dilated blood vessels and a few areas of fibrosis are seen in the pulp tissue (trichrome stain ×200 magnification).

Furthermore, Koh et al[34] believe that MTA stimulates the release of cytokine that, in turn, promotes hard tissue genesis. They concluded that MTA is not an inert dental material, but is rather active in promoting hard tissue formation. The observed presence of a moderate amount of chronic inflammatory infiltration within the pulp tissue is consistent with Cox[35] and Browne et al,[36] who have stated that favorable pulpal responses accompanied by the presence of some chronic inflammatory cells indicate a bacterial-tight seal preventing microleakage.

As observed in the gray MTA specimens, the presence of reversal and resting lines in dentin indicates active resorption and continuous deposition of secondary dentin. The gray MTA pulp capping's effect can also be seen in the root canals, where active deposition of secondary dentin and narrowing of the canals are observed. These dentin deposition observations demonstrate a generalized effect of the gray MTA material throughout the pulp chamber and root canal, while internal root resorption is the more common sequelae with formocresol or ferric sulphate, as reported by Fuks.[31]

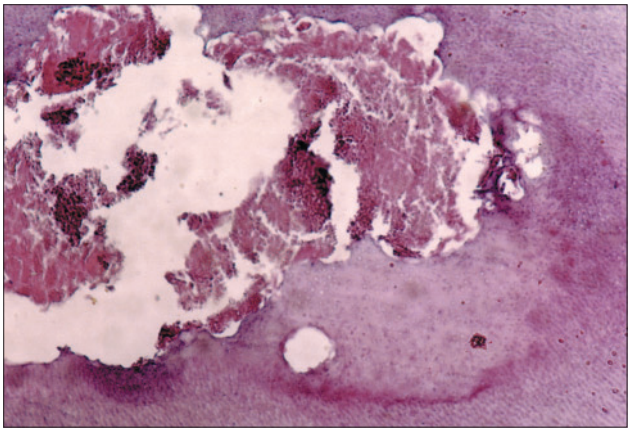

Figure 8. This section, made from a tooth treated with formocresol, shows some secondary dentin formation, but incomplete bridging, necrosis of pulp tissue, inflammatory cell infiltration, and nearly complete absence of an odontoblastic cell layer (hematoxylin-eosin stain ×400 magnification).

Although the white MTA group also revealed considerable dentin bridge formation histologically, most of the samples showed that the pulpal response was generally less favorable than in the gray MTA group. More clinical and radiographic failures were also seen after the pulpotomies treated with white MTA when compared to the other 2 groups. The production of fibrillar secondary dentin is this group's prominent feature. More pulp calcifications were seen in the white MTA specimens than in the gray MTA group, but there was less secondary dentin deposited in the root canals of teeth treated with white MTA than with gray MTA.

Although significant pulpal destruction was the prominent histologic feature seen in the formocresol group, a successful thin dentin bridge was often recognized. This observation is consistent with previous studies by García-Godoy et al[3] and Hill et al[4] implying that the use of formocresol results in pulpal inflammation and necrosis. The clinical success of formocresol is attributed to its bactericidal characteristics, according to Cox et al.[37] Further studies with a larger sample size and longer follow-up periods both clinically and histologically are recommended.

Conclusions

Based on the results of this study, the authors conclude that gray MTA is superior to both white MTA and formocresol as a pulp dressing for pulpotomized primary molars. Further, studies using the newer white MTA as a pulp dressing in pulpotomized primary molars are recommended to confirm this study's results.

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Abstract of the Scientific Literature

Early Problems of Cognition and Behavior in "Epilepsy-only" Children

This article describes a multicenter, prospective, longitudinal, and controlled study of cognitive (educational) and behavioral differences when comparing 51 outpatient schoolchildren, each with recently diagnosed idiopathic or cryptogenic epilepsy, to 48 age- and sex-matched classmate control subjects. All children, both test and control subjects, underwent a neuropsychological assessment of cognition, academic skills, and mental and motor skills 3 times within the first year following diagnosis. Behavior-related questionnaires were completed by the subjects' teachers and parents at each assessment. The test groups' parents were interviewed by a psychologist to: (1) determine how children and their parents were able to adapt to the onset of epilepsy; and (2) determine any family problems present prior to diagnosis. Statistical analysis produced 6 major components characterized as: (1) attention; (2) reaction times; (3) intelligence; (4) academic skills; (5) location learning; and (6) behavior, which exhibited repeated variance.

The major findings were 3-fold: (1) children newly diagnosed as "epilepsy only" were already at risk for educational and behavioral problems in the very earliest stages of the disease, with more than 50% needing special education assistance; (2) test subjects obtained worse scores in principal components of cognition and behavior than the control group; (3) the psychosocial context rather than characteristics of the epilepsy were related to the test groups' performances on cognition and behavior measures. The behavior component, assessed by the ratings of the parents and teachers, yielded the largest difference between the groups.

If these major findings are not remedied, early educational and behavioral problems may end in psychosocial and vocational burdens in adulthood. Children and their parents who do not adaptively react to the adversity of epilepsy have an increased risk of negative reactions, as these cognitive and behavioral sequelae arise from multiconditional vulnerability rather than epilepsy's medical aspects.

Comments: It is interesting that no causative factors could be identified for "epilepsy only," yet this group exhibited decreased cognitive and behavioral skills very early in diagnosis and had statistically significant worse scores in all major components than the control group. The authors' findings tend to indicate a more psychopathologic than organic origin for this decrease in skills following diagnosis, yet the more involved cases had a history of difficult behavior and poor academic skills prior to epilepsy's diagnosis. The inclusion of the test subjects' parental academic skills and educational attainment, along with their past medical history and social standing, may have shed further insight into the decrease in academic and behavioral skills of those with "epilepsy only." **ET**

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