Vital Pulp Therapy with New Materials for Primary Teeth: New Directions and Treatment Perspectives

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Abstract

Vital pulp therapy aims to treat reversible pulpal injury and includes 2 therapeutic approaches: (1) indirect pulp treatment for deep dentinal cavities and (2) direct pulp capping or pulpotomy in cases of pulp exposure. Indirect pulp treatment is recommended as the most appropriate procedure for treating primary teeth with deep caries and reversible pulp inflammation, provided that this diagnosis is based on a good history, a proper clinical and radiographic examination, and that the tooth has been sealed with a leakage-free restoration. Formocresol has been a popular pulpotomy medicament in the primary dentition and is still the most universally taught pulp treatment for primary teeth. Concerns have been raised over the use of formocresol in humans, and several alternatives have been proposed. Controlled clinical studies have been critically reviewed, and mineral trioxide aggregate and ferric sulfate have been considered appropriate alternatives to formocresol for pulpotomies in primary teeth with exposed pulps. In most of the studies reviewed, the caries removal method has not been described. The use of a high-speed handpiece or laser might result in an exposure of a "normal" pulp that would otherwise not be exposed. *(J Endod 2008;34:S18-S24)*

Key Words

Ferric sulfate, formocresol, mineral trioxide aggregate, primary teeth, pulp therapy

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The aim of vital pulp therapy is to treat reversible pulpal injuries in both permanent and primary teeth, maintaining pulp vitality and function (1). In addition to these, in primary teeth it is important to preserve the tooth until its natural exfoliation time, thus preserving arch integrity (2). Vital pulp therapy includes 2 therapeutic approaches: indirect pulp treatment (IPT) in cases of deep dentinal cavities and direct pulp capping (DPC) or pulpotomy in cases of pulp exposure (1).

Advances in biomedical research open avenues for the design of new methods of dental treatment, aiming at regeneration of the dentin-pulp complex. New approaches have been based on the understanding of the molecular and cellular mechanisms regulating dentinogenesis during dental tissue repair and their potential for clinical exploitation (1).

The dental pulp possesses the ability to form a dentin-like matrix (tertiary dentin) as part of the repair in the dentin-pulp organ (3). Vital pulp therapy aims to treat reversible pulpal injury in cases in which dentin and pulp are affected by caries, restorative procedures, or trauma. Whenever the dentin-pulp complex is affected by injury, 3 different physiopathologic conditions might be observed at the dentin-pulp border:

1. In the case of mild injuries as in noncavitated enamel caries or slowly progressing dentinal caries, the odontoblasts might survive, and the odontoblastic layer is stimulated to form a tertiary dentin matrix beneath the injury (reactionary dentin). Reactionary dentin shows many similarities to the primary and secondary dentin and can effectively oppose exogenous destructive stimuli to protect the pulp (4).
2. With severe dentinal injuries without pulp exposure as in rapidly progressing carious lesions or in severe tissue damage caused by cavity preparation, odontoblasts are destroyed subjacent to the affected dentin (5, 6). In an appropriate metabolic state of the dentin-pulp complex, a new generation of odontoblast-like cells might differentiate and form tubular tertiary dentin (reparative dentinogenesis) (3, 7). It must be emphasized that under clinical conditions, the matrix formed at the pulp-dentin interface often comprises reactionary dentin, reparative dentin, or fibrodentin formation. It is impossible to distinguish these processes at the in vivo level, and the process might also be indistinguishable from a biochemical and molecular point of view.
3. In the case of pulp exposure, the amputated pulp can be repaired by itself or after application of capping materials (8–10). Pulp exposure caused by caries shows very limited potential for pulp recovery as a result of bacterial infection of the pulp for a substantial period of time, which compromises the defense reaction (11). As part of the wound healing process in the repairing pulp, the dentinogenic potential of pulp cells can be expressed. Proliferation, migration, and differentiation of progenitor cells can give rise to a new generation of reparative dentin-forming cells (odontoblast-like cells), reconstituting the lost continuum at the pulp-dentin border (12, 13).

Indirect Pulp Treatment

After this brief review of the cellular changes during tooth development and how they are mimicked during tissue repair, we are able to assess the biologic validity of the various vital pulp treatments. In this light, IPT, contrary to what was believed in the past, can also be an acceptable procedure for primary teeth with reversible pulp inflammation, provided that the diagnosis is based on a good history and proper clinical and

radiographic examination, and the tooth has been sealed with a leakage-free restoration (2).

In a recent systematic review on complete or ultraconservative removal of decayed tissue, Ricketts et al. (14) concluded that "in deep lesions, partial caries removal is preferable to complete caries removal to reduce the risk of carious exposure."

Several articles reported the success of this technique in primary teeth (15–19). On the basis of the biologic changes previously described and the growing evidence of the success of IPT in primary teeth, we can recommend IPT as the most appropriate treatment for symptom-free primary teeth with deep caries, provided that a proper, leakage-free restoration can be placed. This issue will be discussed in greater detail further in this symposium.

Direct Pulp Capping

DPC is carried out when a healthy pulp has been inadvertently exposed during an operative procedure. The tooth must be asymptomatic, and the exposure site must be pinpoint in diameter and free of oral contaminants. A calcium hydroxide medicament is placed over the exposure site to stimulate dentin formation and thus "heal" the wound and maintain the pulp's vitality (20).

DPC of a carious pulp exposure in a primary tooth is not recommended but can be used with success on immature permanent teeth. DPC is indicated for small mechanical or traumatic exposures when conditions for a favorable response are optimal. Even in these cases, the success rate is not particularly high in primary teeth. Treatment failure might result in internal resorption or acute dentoalveolar abscess (20).

Presently, DPC should still be looked on with some reservations in primary teeth. This treatment, however, could be recommended for exposed pulps in older children 1 or 2 years before normal exfoliation. In these children, a failure of treatment would not imply the need for a space maintainer after extraction, as it would in younger children.

In a recent article, Caicedo et al. (21) demonstrated good pulp response in primary teeth after DPC or pulpotomy with MTA and concluded that MTA might be a favorable material for pulp capping and pulpotomy in primary teeth.

Pulpotomy

Pulpotomy is still the most common treatment for cariously exposed pulps in symptom-free primary molars. The aim of this treatment is to preserve the radicular pulp, avoiding pain and swelling, and ultimately to retain the tooth, preserving arch integrity (2). Formocresol (FC) has been a popular pulpotomy medicament in the primary dentition for the past 70 years since its introduction by Sweet in 1932, and it is still considered the most universally taught and preferred pulp treatment for primary teeth (22–24). Concerns have been raised over the use of FC in humans, mainly as a result of its toxicity and potential carcinogenicity (25–32).

The International Agency for Research on Cancer classified formaldehyde as carcinogenic for humans in June 2004, leaving the profession to look for other alternatives to FC (31). On the basis of the information available, an expert working group has determined that there is now sufficient evidence that formaldehyde causes nasopharyngeal cancer in humans, a rare cancer in developed countries, limited evidence for cancer of the nasal cavity and paranasal sinuses, and "strong but not sufficient evidence" for leukemia.

There has been a significant amount of discussion in the dental literature about the appropriateness and safety of using aldehyde-based products in pediatric dentistry (29). FC is no longer used in some countries, mainly as a result of safety concerns.

Milnes (33) published an extensive and detailed review of the more recent research on the metabolism, pharmacokinetics, and carcinogenicity of formaldehyde and concluded that formaldehyde is not a potent human carcinogen under conditions of low exposure. He concluded that extrapolation of these research results to pediatric dentistry suggests an inconsequential risk of carcinogenesis associated with formaldehyde use in pediatric pulp therapy.

In a case-control study in which FC pulpotomies were performed in 5- to 10-year-old children, blood samples were taken before (control) and after treatment to observe the mutagenic potential of FC on lymphocytes cultures. No statistically significant differences could be observed in the cultured lymphocytes. FC was mutagenic for one patient, however, leading the authors to raise doubts about the desirability of using this technique in children (34).

No correlation between FC pulpotomies and cancer has ever been demonstrated. Nevertheless, several studies have reported that the clinical success of FC pulpotomies decreases with time, and the histologic response of the primary pulp is "capricious," ranging from chronic inflammation to necrosis (35).

Presently, there are several pulp dressing medicaments that have been proposed to maintain radicular pulp vitality that are equal to, if not better than, FC and can be used as alternatives to pulpotomies in primary teeth. The pulp dressing materials and techniques proposed include: electrosurgery (36, 37), laser (38, 39), glutaraldehyde (GT) (40–44), calcium hydroxide (CH) (45–47), freeze-dried bone (48), bone morphogenetic protein (49), osteogenic protein (50), ferric sulfate (FS) (51–56), mineral trioxide aggregate (MTA) (24, 57–59), and sodium hypochlorite (60).

Although a considerable number of clinical trials and laboratory animal studies have been published on this subject, the Cochrane review found that evidence is lacking to conclude which is the most appropriate technique for pulpotomies in primary teeth (61). The Cochrane review assessment is extremely rigorous, and with the exception of 3 articles, none of the articles evaluated could meet the criteria and were excluded.

Evidence-Based Analysis of Pulpotomy Literature

Loh et al. (62) published an evidence-based assessment of FC versus FS by using a different sieving system including all suitable clinical trials, not only randomized ones. They concluded that both materials were likely to produce similar clinical/radiographic success.

Following Cochrane's criticism regarding the paucity of appropriately designed, statistically assessed investigations and the lack of long-term outcomes, many studies have been reported, and several others have begun to contribute to the literature (32).

Fuks and Papagiannoulis (63) assessed the relevant articles that have appeared after the aforementioned reviews by using the clinically based criteria listed by Curzon and Toumba (64). In this review, the MEDLINE search used generated a total of 358 citations, and the sieving of these articles was conducted by examining the article title and assessing its relevance (62).

All articles were graded according to the aforementioned criteria and classified as A if the article met 90% or more of the criteria; B1 if an article scored from 75%–89%; B2 if it scored between 60%–74%; and C if it scored 59% or less, which meant that it had to be excluded. Even with different weights attributed to the evaluated articles, no conclusion could be reached as to the optimum treatment or technique for pulpally involved primary teeth. In a meta-analysis to compare the clinical and radiographic effects of MTA with FC, Peng et al. (65) reported that MTA was superior to FC. These authors claimed that MTA induces less undesirable responses and might be a suitable replacement for FC.

TABLE 1. Articles Directly Comparing MTA and FC

Direct comparison articles: MTA × FC	Molars, FC (N)	Molars, MTA (N)	Success (clinical), FC N (%)	Success (clinical), MTA N (%)	Success (x-ray), FC N (%)	Success (x-ray), MTA N (%)	Follow-up (mo)
Cuisia et al. (2001)	30	30	28 (93)	29 (97)	23 (77)	28 (93)	6
Agamy et al. (2004)	20	19	18 (90)	19 (100)	18 (90)	19 (100)	12
Jabbarifar et al. (2004)	32	32	29 (91)	30 (94)	29 (91)	30 (94)	12
Farsi et al. (2005)	36	38	35 (97)	38 (100)	31 (86)	38 (100)	24
Holan et al. (2005)	29	33	24 (83)	32 (97)	24 (83)	32 (97)	≤74
Naik and Hegde (2005)	23	24	23 (100)	24 (100)	23 (100)	24 (100)	6

FC, formocresol.

In another meta-analysis that included clinical trials and randomized, clinical trials, Deery (66) concluded that pulpotomies performed with either FS or FC were likely to produce similar results.

Although meta-analysis generally pools data from randomized, clinical trials, they are regarded as observational studies of evidence (67–69). Usually the reviewer identifies the relevant studies from the literature and decides whether to include or exclude them. Therefore, the strength of conclusions drawn from a meta-analysis might only be comparable to that drawn from observational studies, which are open to various forms of bias. Problems, including publication bias and the variable quality of the primary studies, can threaten the validity of meta-analysis (70). Another limitation of meta-analyses is that they all search for relevant articles in electronic databases and are limited to the English language. Most databases date only from 1965. For this reason articles that could have been relevant, particularly on CH or FC pulpotomies, were not included. Language bias can also occur because researchers whose native language is not English are more likely to publish nonsignificant results in non-English journals and significant results in English journals (70).

One of the aims of evidence-based dentistry is to reach an evidence-based conclusion and then translate it into a clinical decision that would result in a better treatment outcome. With these points in mind, this article will consist of critically assessing the randomized and nonrandomized human clinical trials that resulted from a MEDLINE search. This search generated a total of 358 citations, as described by Fuks and Papagiannoulis (63), with the addition of the relevant studies published after that date. Duplicate publications of the same study were excluded. The articles assessed will be limited to the comparisons of FS, MTA, and CH with FC and are presented in Tables 1–3.

Studies Comparing MTA With FC
Cuisia et al. (2001)[71]

This randomized, clinical trial compared MTA with FC, but the randomization method was not reported. Only asymptomatic molars without clinical and/or radiographic evidence of pulp degeneration were included. Pulpotomies were performed in 60 molars by 1 pediatric dentist using a local anesthetic and restored with a stainless steel crown, but there was no mention of the use of a rubber dam. The results were assessed by 2 pediatric uncalibrated dental residents at 6-month follow-up; the clinical success rate was 93% for FC and 97% for MTA, whereas the radiographic success was 77% for FC and 93% for MTA.

Agamy et al. (2004)[57]

This randomized, clinical trial compared gray MTA, white MTA, and FC in 72 molars of 24 children. Only restorable molars without clinical and/or radiographic evidence of pulp degeneration were included. Each child had at least 3 molars with severe carious involvement and received pulpotomies with all 3 medicaments. An additional 15 carious teeth planned for serial extractions after 6 months were selected for the histologic part of the study. All pulpotomies were performed by the same pediatric dentist, and outcome assessment after 12 months was done by 2 "blinded" pediatric dentists. Four children (12 molars) dropped out, and of the remaining 60 teeth in 20 patients, 1 (gray MTA) exfoliated normally, and another 6 teeth (4 white MTA and 2 FC) failed as a result of abscesses. The remaining 53 teeth appeared to be clinically and radiographically successful. In the histologic study, both types of MTA formed thick dentin bridges, but the gray MTA appeared to be better than white MTA and FC as a pulp dressing, because it presented the closest to normal pulp architecture.

Jabbarifar et al. (2004)[72]

This randomized, clinical trial compared MTA with FC in 64 molars assigned to 2 groups by the toss of a coin. The number of pediatric dentists who performed the treatments was not specified, rubber dam isolation was not reported, and all the teeth were restored with SSCs. Outcome assessment of 64 molars remaining at 12 months was done by 2 "blinded" pediatric dentists. The number of molars treated at the baseline and the number of dropouts were not reported. Clinical and radiographic success for MTA was 94% and for FC was 91%.

Farsi et al. (2005)[59]

This randomized, clinical trial compared MTA with FC in 120 molars of 100 children assigned to 2 groups by the toss of a coin. Only restorable molars without clinical and/or radiographic evidence of pulp

TABLE 2. Articles Comparing Directly FS and FC

Direct comparison articles: FC × FS	Molars, FC (N)	Molars, FS (N)	Success (clinical), FC N (%)	Success (clinical), FS N (%)	Success (x-ray), FC N (%)	Success (x-ray), FS N (%)	Follow-up (mo)
Fei et al. (1991)	27	29	26 (96)	29 (100)	22 (81)	28 (97)	12
Fuks et al. (1997)	37	55	31 (84)	51 (93)	27 (73)	41 (93)	35
Aktoren and Gencay (2000)	24	24	21 (88)	21 (88)	19 (80)	20 (84)	24
Papagiannoulis (2002)	60	73	58 (97)	66 (90)	47 (78)	54 (74)	36
Ibrevic and Al-Jame (2003)	80	84	78 (97)	81 (96)	75 (94)	77 (92)	42–48
Huth et al. (2005)	48	49	46 (96)	49 (100)	43 (90)	42 (86)	24
Markovic et al. (2005)	33	37	30 (91)	33 (89)	28 (85)	30 (81)	18

FC, formocresol; FS, ferric sulfate.

TABLE 3. Articles Directly Comparing CH and FC

Direct comparison articles: FC × CH	Molars, FC (N)	Molars, CH (N)	Success (clinical), FC N (%)	Success (clinical), CH N (%)	Success (x-ray), FC N (%)	Success (x-ray), CH N (%)	Follow-up (mo)
Waterhouse et al. (2000)	44	35	37 (84)	27 (77)	37 (84)	27 (77)	To exfoliation
Huth et al. (2005)	48	38	46 (96)	33 (87)	43 (90)	25 (66)	24
Markovic et al. (2005)	33	34	30 (91)	28 (82)	28 (85)	26 (76)	18

FC, formocresol; CH, calcium hydroxide.

degeneration were included. The number of pediatric dentists who performed the treatments was not specified, rubber dam isolation was not reported, and all the teeth were restored with SSCs. At 24 months, 46 molars (38%) were lost, leaving 74 molars for evaluation. All the MTA-treated molars were successful clinically and radiographically (100%). For the FC, clinical and radiographic success was 97% and 86%, respectively.

Holan et al. (2005)[24]

This randomized, clinical trial compared MTA with FC in 64 molars of 35 children assigned to 2 groups by the toss of a coin. The number of operators was not specified, and in 56 molars SSCs were placed, 1 molar received a composite restoration, and the other 7 teeth were restored with amalgam. Clinical outcomes were assessed by 1 pediatric dentist without "blinding." Radiographs were assessed by 3 "blinded" pediatric dentists using a standardized evaluation form for calibration (complete agreement for all cases). Internal resorption was considered a failure only when it reached the bone. Arrested internal resorption, calcific metamorphosis, and pulp canal obliteration were not considered failures.

At 74 months, 2 molars (3%) were lost, leaving 62 molars for evaluation. Clinical and radiographic success was 97% for MTA and 83% for FC, respectively.

Naik and Hegde (2005)[58]

This randomized, clinical trial compared MTA with FC in 50 molars assigned randomly (method not specified) to 2 groups. The inclusion criterion was "asymptomatic deep carious lesion with no frank exposure." Pulpotomies were performed by a postgraduate dentist under local anesthesia and rubber dam. It was not clear whether preoperative radiographs were taken and SSCs were placed 24 hours later. Three teeth were lost to follow-up (2 FC and 1 MTA), and all the remaining teeth were clinically and radiographically successful at the 6-month follow-up.

Studies Comparing FS With FC
Fei et al. (1991)[51]

This randomized, clinical trial compared FS wth FC in 83 molars in 62 children assigned by a table of random numbers to 2 groups. Only restorable molars without clinical or radiographic signs of pulpal degeneration were included. Teeth with pulpal hemorrhage persisting after 2 applications of FS or FC were eliminated. A pediatric dentistry postgraduate student performed all pulpotomies, and 2 pediatric dentists were "blinded" and calibrated before radiographic assessment. At 12 months, 27 molars were lost, leaving 56 molars for assessment. Clinical success for FC was 96% and for FS was 100%; radiographic success was 81% for FC and 97% for FS.

Fuks et al. (1997)[52]

This randomized, clinical trial compared FS with FC in 96 molars in 72 children assigned to 2 groups by a toss of a coin. Only asymptomatic and restorable molars without clinical and radiographic signs of pulp degeneration were included. Three pediatric dentists performed

the pulpotomies under a local anesthetic and with a rubber dam, but outcome assessors were not reported. Molars with pulp canal obliteration (PCO) were not considered failures. The dropout rate was 4% (4/96 molars) after 6–34 months. Clinical success for FC was 84% and for FS was 93%; radiographic success was 80% for FC and 93% for FS. No statistical difference was observed between the 2 groups.

Aktoren and Gencay (2000)[73]

This randomized, clinical trial compared FS, FC, and GT. Only asymptomatic and restorable molars without clinical and radiographic signs of pulp degeneration were included. Clinicians performing the pulpotomies and outcome assessors were not described. At 24 months, clinical success rates for 72 molars were reported to be 88% for both FC and FS, and radiographic success was 80% for FC and 84% for FS.

Papagiannoulis (2002)[74]

This randomized, clinical trial compared FS with FC in 133 molars in 90 children assigned to 2 groups by a toss of a coin. Only asymptomatic and restorable molars without clinical and radiographic signs of pulp degeneration were included. Pulpotomies were performed by 3 pediatric dentists; most molars were restored with SSCs, and a few received composite resin restorations. Outcomes were assessed by a separate "blinded" pediatric dentist. Molars with PCO or nonprogressive internal resorption were not considered failures. Clinical success was 97% for FC and 90% for FS, and radiographic success was 78% for FC and 74% for FS.

Ibrevic and Al-Jame (2003)[54]

This randomized, clinical trial compared FS with full-strength FC in 194 molars in 70 patients allocated alternately to 2 groups. Only restorable molars without clinical and radiographic signs of pulp degeneration were included. Pulpotomies were performed by 1 pediatric dentist, and most molars received SSCs; a few molars were restored with amalgam. Clinical outcomes were assessed by the operator, but radiographic outcomes were assessed by both the operator and another "blinded" evaluator. Calibration was not reported, but both assessors reached consensus on radiographic outcomes. Ten patients (30 molars) dropped out after 42 months. Clinical success rates were 97% in the FC group and 96% in the FS group. The radiographic success rate was 94% in the FC group and 92% in the FS group. No statistical differences were found between the radiographic assessments of both pulpotomy agents.

Huth et al. (2005)[47]

This randomized, clinical trial compared FS, FC, CH, and laser in 107 children. A power calculation estimated the numbers of molars required to achieve statistical significance. Randomization was done by casting a concealed lot from a box of 4 × 50 lots, such that 200 molars were allocated to 4 groups. Only asymptomatic restorable molars without clinical and radiographic signs of pulp degeneration were included. The molars received SSCs or composite resin restorations. Two pediatric dentists performed the pulpotomies under local or general anesthesia and rubber dam, and 2 other "blinded" experienced dentists per-

formed outcome assessments. Intraexaminer and interexaminer reproducibility was optimal ($\kappa = 1.0$). The dropout rate was 8% (16/191 molars), and the remaining participants were examined after 24 months. Clinical success rate was 96% for FC and 100% for FS, and radiographic success was 90% for FC and 86% for FS.

Markovic et al. (2005)[56]

This randomized, clinical trial compared FS, FC, and CH in 104 molars in 104 children assigned randomly to 3 groups. Vital carious-exposed molars with no radiographic signs of pulpal degeneration were included. Pulpotomies were performed by 3 pediatric dentists, and outcomes were assessed by a separate evaluator. The intraexaminer agreement was moderate ($\kappa = 0.70$). The number of molars at baseline and the number of dropouts were not reported. The clinical success rate at 18 months for FC was 91%, for FS was 89%, and for CH was 82%. The radiographic success was 85% for FC, 82% for FS, and 76% for the CH group. These differences, however, were not statistically significant.

Studies Comparing CH With FC

Three articles compared directly CH with FC. Two of them have been summarized previously (47, 56).

Waterhouse et al. (2000)[75]

This randomized, clinical trial compared FC and CH in 84 molars in 52 children assigned to 2 groups by the toss of a coin. Only healthy children with restorable molars without clinical and radiographic signs of pulp degeneration were included. Pulpotomies were performed by clinicians under rubber dam or cotton roll isolation; SSCs were placed "where indicated" (indications not described), and other molars were restored with amalgam, glass ionomer, or compomer. Outcomes were assessed by a separate pediatric dentist, "blinded" and calibrated in a parallel study (77% interexaminer agreement). At 22 months, 5 molars in 3 patients dropped out, leaving 79 molars in 49 children. Clinical and radiographic success was 84% for FC and 77% for CH.

Studies Comparing Laser With FC

Saltzman et al. (2005)[39]

This randomized single-blind, split-mouth clinical trial compared a diode laser pulpotomy with MTA with a conventional FC/zinc oxide–eugenol (ZOE) pulpotomy. A total of 26 pairs of teeth from 16 patients between 3–8 years old were selected on the basis of clinical and radiographic criteria. All teeth were followed up clinically and radiographically for 15 months. A total of 7 laser-MTA–treated teeth were radiographic failures, as opposed to 3 FC/ZOE-treated teeth at 15.7 months; however, these results were not statistically significant. The authors suggested that an improved success rate among a larger patient sample and a longer follow-up period would be required for the laser-MTA pulpotomy to be considered a suitable alternative to conventional FC pulpotomy.

Liu JF (2006)[76]

This clinical study compared the effects of Nd:YAG laser pulpotomy with FC on human primary teeth. Patients without any medically compromised disease were selected from the patient population at a hospital-based dental clinic in Taiwan. Primary teeth that required pulpotomy "because of carious pulp exposure" were selected for this study. Fifty children with an average age of 5 years, 3 months (range, 4–7 years) participated in the study group, and a total of 68 primary molars were treated with the Nd:YAG laser. Forty-four children participated in the control group, and 69 primary molars were treated with diluted FC. Follow-up time was between 6–64 months. In the Nd:YAG laser group, clinical success was achieved in 66 of 68 teeth (97%), and 94% were radiographically successful. In the control group, 85% and 78% achieved clinical and radiographic success, respectively. The success rate of the Nd:YAG laser was significantly higher than that of the FC pulpotomy. The permanent successors of the laser-treated teeth erupted without any complications.

Study Comparing Sodium Hypochlorite With FS

Vargas et al. (2006)[60]

This prospective randomized, clinical study compared the effectiveness of 5% sodium hypochlorite (NaOCl) with that of FS as a pulpotomy medicament in decayed primary molars. Twenty-three healthy patients between 4 and 9 years old with at least 2 primary molars needing a pulpotomy were included in the study. The teeth were clinically and radiographically examined, and the signs/symptoms were recorded at 0, 6, and 12 months. Six-month results were based on the first 32 teeth in the NaOCl group and 28 teeth in the FS group. Twelve-month results were based on 13 teeth in the FS group and 14 in the NaOCl group. At 6 months, 100% clinical success was found in both the FS and NaOCl groups. Radiographic success for FS was 68%, with internal resorption being the most common finding. The NaOCl showed 91% radiographic success. At 12 months, FS had 85% clinical success and 62% radiographic success. NaOCl had 100% clinical success and 79% radiographic success. The authors concluded that preliminary evidence showed that NaOCl can be used successfully as a pulpotomy medicament.

Summary

From this review of the randomized, clinical trials, one can observe that all the studies comparing MTA with FC showed that MTA presented better results, even though in some of them there was no statistical difference as a result of the small number of teeth tested. FS was also better than FC in some studies and similar to FC in others, whereas the 3 studies with CH showed inferior outcomes. It should be emphasized, however, that in most of the studies the method of caries removal has not been described. The use of a high-speed handpiece or laser might result in an exposure of a "normal" pulp that would otherwise not be exposed and not need a pulpotomy or that could be alternatively treated by IPT.

As previously mentioned, one of the aims of evidence-based dentistry is to reach an evidence-based conclusion and then translate it into a clinical decision that would result in a better treatment outcome. It should be kept in mind, however, that improving patient care requires the consideration of other factors including the cost and technique sensitivity of the new medicament.

From the studies previously presented, MTA showed better results in all cases and should be recommended as an alternative to FC. One of the drawbacks of this material, however, is its high cost, and its use in pediatric dentistry practice can become almost prohibitive in some circumstances. Hence, FS can still be considered a valid and inexpensive solution for pulpotomies in primary teeth (2).

A recent preliminary evaluation of sodium hypochlorite showed promising results when compared with FS. The follow-up time, however, is only 1 year. Longer follow-up and more clinical studies are needed to confirm these results.

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