

Conference Paper



Indirect Pulp Capping and Primary Teeth: Is the Primary Tooth Pulpotomy Out of Date?

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Abstract: *Formocresol pulpotomy (FP) in the United States is most frequently used to treat asymptomatic caries near the pulp in primary teeth. Indirect pulp therapy (IPT) is also indicated and has a significantly higher long-term success. Pulpotomy is thought to be indicated for primary teeth with carious pulp exposures, but research shows the majority of such teeth are nonvital or questionable for treatment with vital pulp therapy. IPT has a significantly higher success in treating all primary first molars, but especially those with reversible pulpitis compared with FP. The purpose of this article was to review the dental literature and new research in vital pulp therapy to determine the following: (1) Is a pulpotomy indicated for a true carious pulp exposure? (2) Is there a diagnostic method to reliably identify teeth that are candidates for vital pulp therapy? (3) Is primary tooth pulpotomy out of date, and should indirect pulp therapy replace pulpotomy? (Pediatr Dent 2008;30:230-6)*

KEYWORDS: INDIRECT PULP THERAPY, PULP EXPOSURE, PULPOTOMY

The guidelines of the American Academy of Pediatric Dentistry (AAPD) on pulp therapy for primary and young permanent teeth states that a pulpotomy is a procedure in which the coronal pulp is amputated, and the remaining radicular pulp tissue is treated with a medicament or electrocautery to preserve the pulp's health.¹ The guidelines state the objective of a pulpotomy is to keep the remaining pulp healthy without adverse clinical signs or symptoms or radiographic evidence of internal or external root resorption. The AAPD guidelines further state that there is only one other choice for vital pulp therapy in primary teeth where caries approach the pulp. This choice is indirect pulp therapy (IPT), because the direct pulp cap in a primary tooth is contraindicated for carious exposures.¹ IPT is a procedure in which the caries closest to the pulp is left in place and covered with a biocompatible material, and the tooth is restored to prevent microleakage. The objectives of treatment are the same as for a pulpotomy.¹

For deep caries in primary teeth, the indications for IPT and pulpotomy are identical for reversible pulpitis or a normal pulp when the pulp is judged to be vital from clinical and radiographic criteria.¹ The difference occurs when the caries removal process results in a pulp exposure; a pulpotomy is then undertaken. IPT purposely avoids an exposure by leaving the deepest decay in place. IPT is clearly not indicated when

the pulp is exposed by caries, but is pulpotomy indicated for a carious pulp exposure? For deep caries with possible radiographic exposures that are asymptomatic, which is the better choice of treatment, IPT or pulpotomy?

The purpose of this article was to review the dental literature and new research in vital pulp therapy to determine the following: (1) Is a pulpotomy indicated for a true carious pulp exposure? (2) Is there a diagnostic method to reliably identify teeth that are candidates for vital pulp therapy? (3) Is primary tooth pulpotomy out of date, and should IPT replace pulpotomy?

Is Pulpotomy Indicated for Carious Exposures?

A primary tooth pulpotomy should be performed on a tooth judged to have a vital pulp.¹ After the coronal pulp is amputated, this leaves behind vital radicular pulp tissue that has the potential for healing and repair in 3 general ways, according to Rodd.² First, the remaining radicular pulp can be rendered inert, such as by using formocresol. It fixes or denatures the vital pulp so it is no longer pulp tissue in addition to its bactericidal properties. Second, the radicular pulp might be preserved through minimal inflammatory insult by using a hemostatic agent such as ferric sulfate to form a clot barrier to preserve the deeper remaining pulp tissue. The third pulpotomy mechanism encourages the radicular pulp to heal and form a dentin bridge by using calcium hydroxide or mineral trioxide aggregate (MTA).

What is the histologic and clinical research that can help dentists determine which teeth with deep caries are vital and, thus, candidates for pulpotomy? Reeves and Stanley³ found that as long as the advancing edge of the carious lesion was

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1.1 mm from the pulp, no significant pathologic changes were evident in permanent teeth. Once the caries approached within 0.5 mm of the pulp and the reparative dentin was involved, then significant pathologic changes were noted. Shovelton⁴ examined permanent teeth and showed that as caries approximated 0.25–0.3 mm of the pulp, hyperemia and pulpitis were seen.

Regarding the effect of pulp exposures on the pulp's capacity to repair, Lin and Langland⁵ showed that when no pulp exposure occurred from caries, the pulp's repair capacity was excellent. After a carious exposure, however, it was questionable and unpredictable. They also found that in teeth with a history of pain, the pulp chamber would have an area of necrosis often extending into the radicular pulp. Others have stated that the dentist risks displacing infected dentin chips into the pulp when performing total excavation of deep carious lesions, thus increasing the risk of pulpal inflammatory breakdown.⁶

Stepwise caries removal in permanent teeth thought to have radiographic pulp exposures has been proposed as a method to minimize pulp exposures and preserve vitality.^{7,8} Caries excavation is a 2-appointment procedure. Initially, the lesion's periphery is made caries-free, while the center of the caries is partially removed to leave moist, soft dentin over the pulp. Then, calcium hydroxide and a temporary filling are placed for 6–12 months. The lesion is then re-entered, and all the caries is removed. Bjørndal et al⁷ found no pulp exposures on re-entry in 31 permanent teeth by using stepwise caries removal. Leskell et al⁸ tested stepwise caries removal versus conventional in 127 permanent teeth with a patient mean age of 10.2 years. After 8–24 months, stepwise removal resulted in approximately 18% pulp exposure versus 40% for conventional caries removal.

Many of these permanent tooth findings likely apply to primary teeth. Rodd² stated that carious primary and permanent teeth showed similar neural changes when mounting a pulpal defense to deep caries. Rodd found that primary and permanent teeth have similar vascularity, except in the midcoronal region, and showed a similar degree of vasodilatation and new vessel formation with caries progression.

Eidelman et al⁹ studied severely decayed primary incisors with no pulp pathology in nonrestorable teeth from 20- to 42-month-old children. After fixation, caries was removed with a slow-speed round bur. A sharp explorer was used to evaluate total caries removal and check for a pulp exposure. Teeth without pulp exposures and no total necrosis likely as a result of trauma were histologically diagnosed as treatable with vital pulp therapy in 23 of 26 cases (88%). By contrast, 16 of 24 (67%) of the incisors judged to be nontreatable (total necrosis) or questionable (chronic partial pulpitis) for treatment with vital pulp therapy had a carious pulp exposure, leaving only 33% that were unquestionably vital. Dentists might think they can obtain a 90% level of pulpotomy success in such a case. The simple mathematics of 33% (chance of finding a vital pulp) x 90% (chance of pulpotomy success), however, would equal a 30% chance of a cariously exposed tooth having

a successful pulpotomy. From these histologic and clinical findings, the following conclusions can be drawn:

1. Primary tooth pulpotomy requires a vital radicular pulp, no matter what form or type of pulpotomy procedure is used.^{1,2} Teeth with a carious pulp exposure have a low likelihood of being totally vital⁹ and are, thus, poor candidates for vital pulpotomy.
2. Stepwise caries removal will result in fewer pulp exposures than total caries removal performed in 1 visit.^{7,8}
3. For teeth without carious pulp exposures, performing a pulpotomy likely increases the chance of displacing infected dentin chips into the pulp and impairing the pulp's repair capacity.^{5,6}
4. The pulp's repair capacity is excellent when the carious lesion remains 1 mm or more away from the pulp.³

Is There a Diagnostic Method to Identify Teeth with Deep Caries That Are Symptomless or Questionable, Yet Are Candidates for Vital Pulp Therapy?

Identifying those teeth with deep caries that are vital and treatable with vital pulp therapy leads to this article's second purpose, which was to describe a new method to reliably diagnose these teeth. Initially placing an intermediate, therapeutic, temporary restoration by using glass ionomer caries control (GICC) for 1–3 months before starting pulp therapy has been shown to be an excellent method of diagnosing the pulp's vitality. No anesthesia is used to perform minimal caries excavation with spoon excavators or slow-speed round burs and is a form of alternative restorative treatment (ART)¹⁰ or stepwise caries removal.⁷ This procedure takes less than 5 minutes and can be done at the initial examination visit of a child presenting with multiple open carious lesions.

GICC is indicated in cavitated carious lesions to diagnose their vitality in teeth with signs and symptoms of reversible pulpitis or a symptomless tooth thought to have no pulpitis before instituting any pulp therapy.¹¹ The technique involves minimally removing the superficial, nonpainful decay by using a slow-speed no. 4 or 6 round bur or spoon excavation. A glass ionomer temporary filling is then placed by using a material such as Fuji IX (GC America Inc, Alsip, IL), Ketac Molar (3M ESPE, St Paul, MN), Voco Ionofil Molar AC (Voco GmbH, Cuxhaven, Germany), or a resin-modified glass ionomer. A matrix band does not have to be used, but the intermediate therapeutic temporary restoration should not be in occlusion. After 1–3 months of GICC, if the tooth has been asymptomatic and shows no signs of irreversible pulpitis clinically or on a new radiograph, vital pulp therapy can be instituted by using IPT or pulpotomy (Fig. 1).

Numerous studies have reported on the biologic effects of a glass ionomer temporary filling. Bonecker et al¹² studied dentin samples in 40 primary molars before and after ART excavation. The total bacterial count and mutans streptococci were

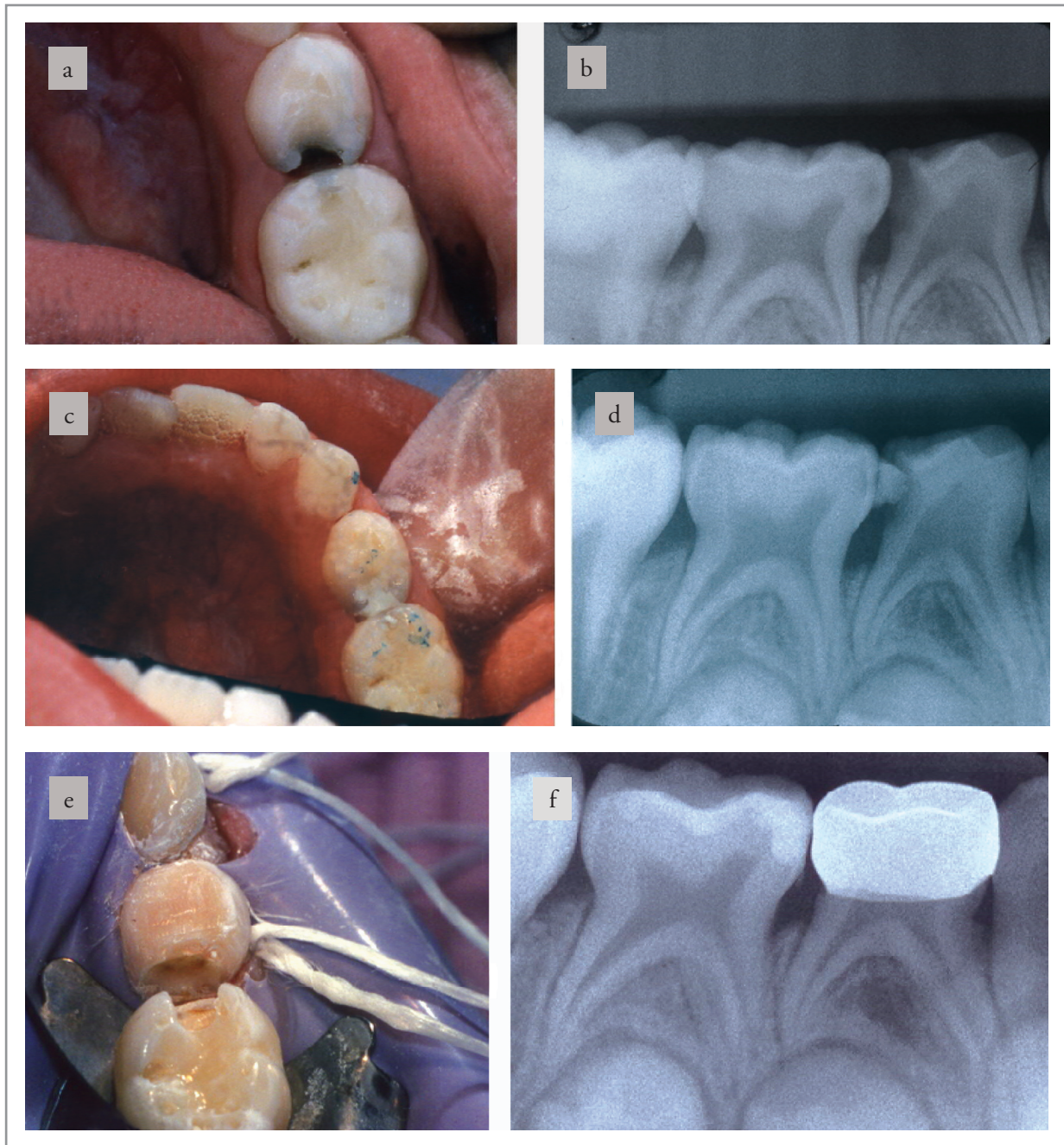


Figure 1. Example of using glass ionomer caries control to diagnose reversible pulpitis or food impaction in a mandibular first primary molar with a history of pain to chewing sweets and solid foods for 2–3 weeks. (a) Preoperative view. (b) Preoperative radiograph. (c) View immediately after glass ionomer placement. (d) Two months after caries control. Pain stopped from day glass ionomer placed. No clinical or radiographic sign of irreversible pulpitis. (e) View of IPT with a glass ionomer base. (f) Tooth 16 months after treatment without signs of pain or irreversible pulpitis clinically or on the radiograph.

significantly reduced from the excavation process alone. Loyola-Rodriguez et al¹³ showed in vitro that all glass ionomer liners had good antibacterial activity against *Streptococcus sobrinus* and *S. mutans* associated with their fluoride release.

Wambier et al¹⁴ published an *in vivo* study of 32 primary molars with open deep carious lesions. Radiographs and examinations excluded teeth with apical pathosis. Initially, carious

dentin samples were taken, and then minimal caries excavation was performed followed by a resin-modified glass ionomer temporary filling. After 30 and 60 days of temporization, the second dentin samples showed that total bacterial counts decreased significantly ($P < .05$), and all bacterial strains had similar trends in both time periods. Scanning electron microscopy inspection of dentin samples in the same time frames showed dentin

reorganization and narrower dentin tubules. The authors believed the results suggested that sealing the cavitated lesion with glass ionomer contributes to remineralization. Only the outer carious layer needs to be removed to accomplish this result. Oliveira et al¹⁵ reported on 32 permanent teeth after minimal caries excavation and temporization for longer time periods. They concluded that total caries removal did not seem essential to stop caries progression.

Regarding the effect of glass ionomer on the subsequent vital pulp therapy, Vij et al¹¹ reported that GICC temporization for 1–3 months increased success of the subsequent vital pulp therapy from 79% to 92%. Teeth temporized with zinc oxide–eugenol, however, had a success rate of 67%. They also reported a “drying out” effect of the moist caries on re-entry after GICC similar to that reported by Bjorndal et al⁷ after 6–7 months of stepwise caries removal.

Another recently completed study reported on GICC’s diagnostic success in deeply cavitated carious lesions.¹⁶ A group of primary molars had GICC after minimal caries excavation for a mean time of 3.5 months. The GICC intermediate therapeutic temporary restoration had to have remained intact without displacement for 1–4 months. Another group of primary molars had no GICC. Both groups had IPT or formocresol pulpotomy and were restored with an immediate steel crown the day of treatment and were followed for a mean time of more than 3 years. Diagnostic success was based on the vital pulp therapy success, or the tooth was successfully diagnosed with irreversible pulpitis after 1–3 months of GICC. The GICC group showed a significant increase ($P < .001$) in the subsequent vital pulp therapy success (98%) versus the non-GICC group’s vital pulp therapy success (75%). There was a subgroup of 18 teeth that presented with pain and/or a questionable diagnosis of their vitality.

All received GICC initially for 1–4 months to diagnose the tooth’s vitality. The GICC produced the correct diagnosis for all the teeth in that 7 molars returned with signs of irreversible pulpitis and were extracted. For the other 11, however, the pain was diagnosed as reversible, and all were treated with vital pulp therapy successfully.

From these microbiologic and clinical studies, the following conclusions can be made on using glass ionomer caries control:

1. Treating primary teeth with deeply cavitated carious lesions after minimal excavation with glass ionomer caries control for 1–3 months initially before instituting pulp therapy causes the bacteria to significantly decrease within the lesion.^{13,14} In vital, symptomless teeth with apparent radiographic exposures or near exposures, treating them with caries control will likely stop caries progression.¹⁵
2. GICC for 1–3 months changes the character of the dentin so that it is drier and harder, and the affected dentin likely remineralizes similar to dentin after stepwise excavation.^{7,11,14}
3. Using GICC as a diagnostic tool for 1–3 months in teeth with symptomless radiographic exposures or ones with pain and questionable vitality will diagnose those that can be treated successfully with vital pulp therapy 98% of the time.¹⁶

Is the Primary Tooth Pulpotomy out of Date for Treatment of Deep Caries and Should IPT Replace Pulpotomy?

Knowing the pulpal diagnosis of primary teeth with deep caries by using GICC should greatly improve the chance of any vital pulp therapy. This leads to the article’s third purpose: Is IPT or pulpotomy the best choice for vital pulp therapy for deeply cavitated carious lesions?

Most pulpotomy success decreases over time from 90% or more initially (6–12 months) to 70% or less after 3 years or more^{11,20,22} (Table 1, Figure 2). The MTA pulpotomy appears to have a higher long-term success rate (>90%) than other pulpotomy types.^{23–25} Yet these reports generally are of shorter duration (only one >24 months)²⁵ and have small sample sizes (=38 teeth) from which to draw strong conclusions. Most of these MTA pulpotomy studies were performed on teeth with symptomless radiographic exposures, and most had immediate steel crowns placed after pulpotomy. The immediate crown should have minimized microleakage and increased pulpotomy success compared with a large amalgam,²⁷ which had been used in other pulpotomy studies.^{17,27} A recent meta-analysis of MTA versus formocresol pulpotomy studies suggested that MTA was superior to formocresol as a result of its lower failure rate.²⁶

IPT usually shows success rates of 90% or greater no matter the technique, medicament, or time periods (Table 2, Figure 2). IPT’s long-term success (3–4 years) surpasses all other pulpotomy studies, with the possible exception of the 1 long-term MTA study.²⁵ There have been various medicaments used for IPT, from calcium hydroxide,^{28–30} glass ionomer,^{11,17} to none,³⁰

Table 1. ALL TYPES OF PULPOTOMY USUALLY SHOW DECREASED SUCCESS OVER TIME

References	Pulpo'tomy	Success (%)	Time (mos)
Dean et al 2002 ¹⁸	Formocresol	92	6-12
Huth et al 2005 ¹⁹	1/5 formocresol	85	24
Rolling and Thylstrup 1975 ²⁰	Formocresol	70	36
Vij R, et al 2004 ¹¹	Formocresol	70	40
Smith et al 2000 ²¹	Ferric sulfate	74-80	19
Casas et al 2004 ²²	Ferric sulfate	67	36
Eidelman et al 2001 ²³	Mineral trioxide aggregate	100	13
Jabbarifar et al 2004 ²⁴	Mineral trioxide aggregate	94	12
Holan et al 2005 ²⁵	Mineral trioxide aggregate	91*	38

* Internal root resorption was not always considered failure; Peng et al 2006²⁶ calculated MTA success at 91% counting internal resorption.

all of which did not significantly change IPT's success rates, as shown in Table 2. Even using dental students of vastly different abilities and likely different techniques, as reported by Al-Zayer et al,²⁹ did not significantly decrease IPT's success below 95%. The type of final, immediate restoration did not alter IPT's success when steel crowns were compared with composite fillings and glass ionomers.^{11,30} Even when no medicament was placed for IPT and the composite filling was bonded to the remaining decay and decay-free dentin, Falster et al³⁰ reported success greater than 90%.

How are pulpotomy and IPT being taught and practiced in the United States? Dunston and Coll³¹ in 2005 surveyed 48 of the 56 pediatric program directors in the U.S. dental schools and 689 of the board-certified pediatric dentists. They found that 76% of the dental schools taught either diluted or full-strength formocresol pulpotomy, whereas the other 24% taught ferric sulfate. Of the 689 pediatric dentists, 81% used diluted or full-strength formocresol, 18% ferric sulfate, and 1% some other type of pulpotomy (electrocautery, MTA, etc). Formocresol remains the overwhelming choice for pulpotomy,

signifying the toxic concerns regarding formocresol do not seem to be a concern for most schools or practicing dentists. The International Agency for Research on Cancer stated in a 2004 press release that formaldehyde causes nasopharyngeal cancer.³² Milnes³³ in 2006 disputed the cancer concern by stating that the amount of formocresol in a pulpotomy was likely such a small amount that formocresol pulpotomy was a low-exposure condition. Zazar et al³⁴ found that when studying the white blood cells after formocresol pulpotomy in 20 children, 1 child showed a 6-fold increase in white blood cell chromosomal abnormalities. From a statistical standpoint, they believed formocresol was not mutagenic, but further studies were needed to verify this.

The 2005 survey³¹ also had a clinical scenario question regarding deep caries removal in a primary second molar in a 5-year-old. Seventy percent of the program directors and more than 80% of the pediatric dentists reported that a pulpotomy was the treatment of choice over IPT. It appears that IPT is not emphasized in U.S. dental schools as a method to treat deep asymptomatic caries, and most dentists practice the way they were taught. In addition, most pediatric dentists believe it is best to enter the pulp and do a formocresol pulpotomy, even though long-term formocresol pulpotomy success is significantly lower than IPT.^{11,17,20,30}

Other factors need to be considered when choosing IPT or pulpotomy for deep caries in primary teeth. Vij et al¹¹ studied IPT and pulpotomy success treating molars with reversible pulpitis pain. They reported that in 20 first primary molars with such pain, IPT success was 85%, which was significantly better ($P=.04$) than the 53% in 19 primary first molars treated with formocresol pulpotomy. They also found that there was significantly ($P=.04$) low success (61%) when first primary molars were treated with formocresol pulpotomy compared with the 92% success with IPT in these molars. When the data of Holan et al²⁷ were tested with χ^2 analysis; it also showed a significantly lowered success for formocresol pulpotomy in primary first molars.

Another concern in the choice of using IPT or pulpotomy is the early exfoliation of pulpotomized teeth. More than 35% of formocresol pulpotomies exfoliate significantly earlier (>6 months) than nonpulpotomized teeth, whereas IPT-treated teeth exfoliate normally.^{11,17} In addition, pulpotomies cost more than 2.3 times more than IPT, on the basis of published dental insurance reimbursement for the 2 procedures.^{35,36} In the United States, however, most dental insurers do not cover IPT for primary teeth, which might result in less utilization. For a tooth with deep caries 1 mm away from the pulp, IPT or pulpotomy can be performed. The pulpotomy could be more painful, because profound anesthesia is always needed for a pulpotomy, whereas the IPT requires no pulpal entry and, therefore, is potentially less painful.

Table 2. INDIRECT PULP THERAPY (IPT) STUDIES SHOWS SUCCESS RATES OF 90% OR GREATER OVER TIME USING DIFFERING TECHNIQUES AND MEDICAMENTS

	IPT medicaments	Success (%)	Time (mos)	Sample (n)
Nirschl and Avery 1983 ²⁸	Calcium hydroxide	94	6	33
Al-Zayer et al 2003 ²⁹	Calcium hydroxide	95	14 (median)	187
Falster et al* 2002 ³⁰	—	90 †	24	48
Vij et al 2004 ¹¹	Glass ionomer	94	40	108
Farooq NS, et al 2000 ¹⁷	Glass ionomer	93	50	55

* Adhesive resin alone without a liner or calcium hydroxide liner and adhesive resin.

† Combined success of both groups.

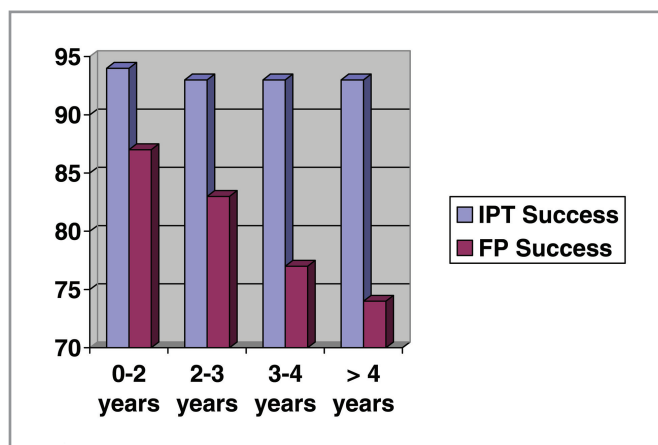


Figure 2. Long-term success rates of formocresol pulpotomy and IPT were statistically different starting in the 2- to 3-year follow-up grouping. Reproduced with permission from Farooq NS, Coll JA, Kuwabara A, Shelton P. Success rates of formocresol pulpotomy and indirect pulp therapy in the treatment of deep dentinal caries in primary teeth. *Pediatr Dent* 2000;22:278–86.

When performing IPT and leaving residual decayed dentin, what are the concerns of leaving this decay after a 1-visit IPT?. Aponte et al³⁷ reported performing indirect pulp capping with calcium hydroxide followed by amalgam restorations in 30 primary molars. After 6–46 months (mean, 29 months), the amalgam and calcium hydroxide were removed, and the carious dentin that had been left behind cultured. In 28 of 30 teeth (93%), the residual carious dentin was sterile. Oliveira et al¹⁵ studied 32 permanent teeth judged by radiographs to have a pulp exposure. From digitized radiographs taken 6–7 months after partial caries removal followed by temporary fillings, there was mineralized improvement in the carious dentin over time. Finally, the 10-year prospective study by Mertz-Fairhurst et al³⁸ conclusively showed that in 85 teeth after obvious occlusal caries was successfully sealed from microleakage, after 10 years in vivo, there was no progress of the caries in permanent teeth.

The following conclusions on choosing IPT or pulpotomy can be drawn from these studies:

1. Formocresol and ferric sulfate pulpotomy have a significantly lower long-term success for treatment of deep caries compared with IPT.^{11,17,20,30} Most U.S. pediatric dentists currently choose to use formocresol pulpotomy over IPT.³¹
2. IPT has been shown to have a significantly higher success rate for teeth with reversible pulpitis compared with formocresol pulpotomy.¹¹
3. IPT shows higher long-term success rates than any pulpotomy other than possibly MTA (Tables 1 and 2). MTA pulpotomy has not been shown to be effective in treating teeth with reversible pulpitis.
4. IPT is less expensive, has fewer potential side effects, and does not exhibit early exfoliation as pulpotomy does.^{11,17,35,36}

Conclusions

Controversy persists as to the best way to perform vital pulp therapy, and additional research is needed to see whether MTA pulpotomy performs as well as IPT. From the present review of the literature and research, the following conclusions can be made:

1. Do not treat carious exposures in primary teeth with pulpotomy or direct pulp caps. Consider pulpectomy or extraction because of the high chance of irreversible pulpitis and failure of vital pulp therapy after a carious pulp exposure.
2. For deep caries approaching the pulp, the choice of IPT or pulpotomy is up to the treating dentist.
3. Use glass ionomer caries control for deep cavitated lesions to diagnose the status of the pulp with or without history of pain to attain the highest success for vital pulp therapy. Stay out of the pulp by using IPT for a higher long-term chance of success compared with formocresol and ferric sulfate pulpotomy.

4. IPT has been shown to have a lower cost, higher success long-term, better exfoliation pattern, and better success treating reversible pulpitis than pulpotomy.

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Conflict of Interest: James A. Coll, DMD, MS, is a paid consultant to the Maryland State Dental Board in the review of dental charts of pediatric patients.

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