Indirect pulp treatment of primary posterior teeth: a retrospective study

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Abstract

Purpose: This study was performed to assess retrospectively the clinical and radiographic success of indirect pulp treatment (IPT) on primary posterior teeth, and to compare the influence of caries risk, skills of the operator, and restorative material on the success of IPT.

Methods: A retrospective review of records of patients treated with IPT in the pediatric dental clinic at The University of Michigan, School of Dentistry from July 1993 through July 1999 was completed in January 2000. Two hundred fifty-five records with IPT were reviewed, from which 132 patients met the inclusion criteria, with 187 primary posterior teeth treated with an IPT. The patients were followed clinically and radiographically for a time ranging between 2 weeks to 73 months. Data were analyzed using survival analysis methods.

Results: The success of IPT was 95% (178/187 teeth), with only 9 failures. The 1-year probability of survival of each tooth was estimated to be 96% using an exponential survival model. The use of a base over a calcium hydroxide liner significantly increased the success rate of IPT (P=.0095). The use of a stainless steel crown (SSC) after an IPT was significantly more successful than the use of an amalgam (P=.026). IPT performed on primary first molars failed more frequently than on second primary molars (P=.045). There was no significant difference between maxillary and mandibular primary molars.

Conclusions: Indirect pulp treatment is a successful technique and should be considered as an alternative pulp therapy procedure in deeply carious primary posterior teeth. The use of a base over the liner in addition to a SSC dramatically increases the success of an IPT. (*Pediatr Dent*. 2003;25:29-36)

KEYWORDS: INDIRECT PULP TREATMENT, PULP THERAPY, PRIMARY TEETH, CALCIUM HYDROXIDE, STAINLESS STEEL CROWNS

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Review of literature

Historically, the indirect pulp-capping (IPC) procedure was advocated more than 200 years ago as a conservative pulp therapy. Ripp[1] reported that Fauchard, in 1746, advocated a conservative treatment of extensively carious teeth. He recommended the retention of some caries because, if the caries were completely removed, a pulp exposure would occur. The term indirect pulp capping (IPC) was recently replaced by the term indirect pulp treatment (IPT; American Academy of Pediatric Dentistry Reference Manual)[2]; therefore, the authors use the term IPT throughout this paper.

Others believed that leaving caries behind was a source of infection, and thus completely unacceptable. Black was against pulp capping pointing out that any successful capping occurred only in children where the root canals were still large. In 1908, Black felt that no practitioner could justify leaving decay behind.[3] The impossibility of obtaining complete sterilization of the remaining carious dentin led several researchers to use a number of agents, most of which were intended to sterilize residual carious dentin. These agents include trichloride of iodine, dichloride of mercury, hydrogen peroxide, oil of cloves, and silver nitrate. Because of the caustic nature of these agents and their

potential to damage vital pulp tissue, the use of the agents was strongly questioned and they are no longer in common use.[4-8]

Despite the controversy and the opposition to indirect pulp treatment (IPT) and the reduction since 1960 in the popularity in dental schools within the United States,[9] multiple studies were conducted before and after 1960 to verify the success of this technique. Most of these studies focused on the materials and medicaments, namely calcium hydroxide $Ca(OH)_2$ and zinc oxide eugenol (ZOE) used as a liner or base to cover the remaining carious or demineralized dentin before and after IPT.[2,7,8,10] Clinical studies have shown that $Ca(OH)_2$ compounds or ZOE cement used as IPT agents usually had high degrees of success (76%-100%).[7,11-17]

The basic definition of an indirect pulp capping is "The procedures or steps taken to protect or maintain the vitality of the carious tooth that, if completely excavated, the decay would result in a pulp exposure."[18,19] Although there are no precise methods to determine how much carious dentin is to be removed, clinical judgment suggests to remove dentin that is obviously necrotic and amorphic and to leave dentin that is firmer and still has the appearance of being intact.[8] In addition, before performing IPT, all the caries at the dentinal enamel junction must be removed.[20] The superficial layer of the carious dentin that needs to be removed is called the infected dentin.[21] This layer contains the majority of microorganisms and their toxic products that are also the source of continuous insult to the pulp. The infected layer must be removed to allow the healing of the dental pulp.[22,23] The deep layer or the decalcified dentin is called the affected dentin; this layer has only a few microorganisms.[21] The affected layer can be left in place without any adverse effect on the dental pulp.[23]

Many studies show 70%-100% reduction in the numbers of bacterial colonies in the remaining carious dentin after reentry following IPT.[9,24-27] Most of these studies performed a reentry 6 to 12 months after the initial IPT. Bjorndal (1997) examined the affect of $Ca(OH)_2$ on the residual carious dentin after an interval of 6 to 12 months. He evaluated the association of microbiological status and clinical dentin alteration and found no evidence of a pulpal exposure and few microorganisms after the removal of the residual carious dentin. In addition, the consistency of the residual dentin changed from soft (before treatment) to medium to hard (after reentry several months later).[28]

A clinical study conducted by Damele (1961) to verify the effectiveness of the IPT technique showed almost 100% success after lining the carious dentin with $Ca(OH)_2$.[29] Dimaggio (1963) performed a similar study where he treated 351 teeth by IPT that had no pulpal or radiographic signs and symptoms and concluded that favorable results were obtained in 99% of the cases treated with this technique.[30]

A retrospective study to compare the success rate of indirect pulp treatment (IPT) and pulpotomy was conducted by Farooq (July 2000).[31] Fifty-eight primary molars were treated with IPT where $Ca(OH)_2$ was not used as a liner. All teeth received only a base of a resin modified glass ionomer (Vitrebond) followed by a SSC cemented with zinc phosphate cement. Teeth were followed from 2 to 7 years clinically and radiographically. The study reported a 93% success of the teeth for a mean period of 4 years.[31] A retrospective study by Krusky reported the success rate of IPT on primary molars was 91% over an average of 3 years of follow up.[32]

A prospective randomized clinical trial that compared the success rate of IPT with and without a liner of calcium hydroxide was published by Falster (March 2002). Forty-eight primary molars with deep occlusal carious dentin were treated with or without $Ca(OH)_2$ as a liner and then restored with an adhesive resin system. Teeth were followed for 2 years with a 90% success rate with or without $Ca(OH)_2$ as a liner.[33]

The purpose of this retrospective study was to assess the clinical and radiographic success of IPT on primary posterior teeth and to verify previous retrospective studies. An additional study purpose was to examine the success of IPT in relation to caries risk, skills of the operator, and type of restorative material used.

Methods

A retrospective review of records of patients treated with IPT was completed in January 2000 following approval by the University of Michigan Institutional Review Board. The patients' records reviewed were from the graduate and undergraduate pediatric dental clinics at The University of Michigan School of Dentistry in Ann Arbor, Mich.

The historical information collected from the records consisted of demographic information, teeth treated, date of treatment, type of liner/base (luting cement), type of restoration, experience of the clinician (graduate and undergraduate), outcome of each tooth clinically and radiographically over time, retreatment if applicable, and the exfoliation date compared to the contralateral side if the information was available.

Two hundred fifty-five records were reviewed, which accounted for all the patients treated by an indirect pulp treatment in the pediatric dentistry clinics between July 1993 through June 1999 (6 years). From the 255 records, 132 patients met the selection criteria and had the information needed to complete the study. From the selected group of patients, 187 primary posterior teeth were treated with an IPT. Children treated with this procedure were between 18 months to 12 years of age. To maintain confidentiality of patient's information, each patient was given an identification number.

A standard clinical procedure was followed by all faculty and students in the clinic for an IPT or a pulpotomy. Faculty selected teeth for IPT only if there was deep dental caries with no history or recurrent pain except for complaints of impaction from food when eating.

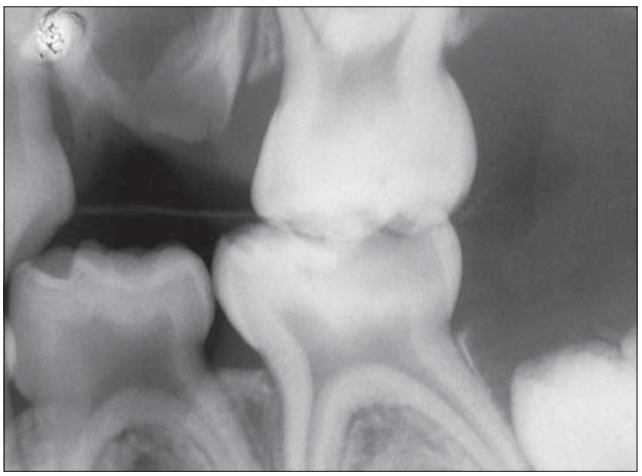

Figure 1a. Case A; a preoperative bitewing radiograph of an asymptomatic mandibular left second primary molar with deep carious dentin.

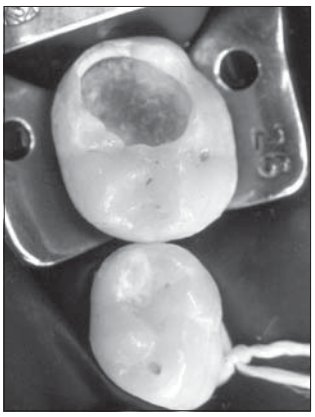

Figure 1b. Case A; carious dentin left behind prior to placing $Ca(OH)_2$ and a final restoration on the mandibular left second primary molar.

Radiographically, the tooth may have appeared to have a pulpal exposure but there were no signs of periapical or furcation pathology. Teeth treated with IPT were not mobile or sensitive to percussion, since these signs would indicate pulp degeneration and periapical involvements; both are contraindicated for IPT. Root length was not a factor in the selection criteria.

After reviewing the radiograph and assuring that the tooth was asymptomatic, a local anesthetic was administered and rubber dam placement was performed. The removal of all carious dentin around the periphery of the lesion was completed, leaving enough carious dentin over the pulp chamber and horns to avoid a mechanical exposure (Figures 1a and 1b). The remaining carious dentin could be stained, leathery, granular in texture, or contain islands of soft dentin.[33,34] A thin layer of calcium hydroxide (Dycal, Dentsply/Caulk, Milford, Del) was placed over the remaining carious dentin. When indicated, a base material of reinforced zinc oxide eugenol (IRM, Dentsply/Caulk) or a resin modified glass ionomer (Vitrebond, 3M, Minneapolis, Minn) was applied and then a final restoration was performed. If a stainless steel crown was used, the base material was also the luting agent (Fynal, Dentsply/Caulk) or a resin modified glass ionomer (Vitrebond; Figures 2a and 2b).

Inclusion criteria:

1. all primary posterior teeth treated by indirect pulp treatment;
2. all patients treated between the ages of 18 months and 12 years;

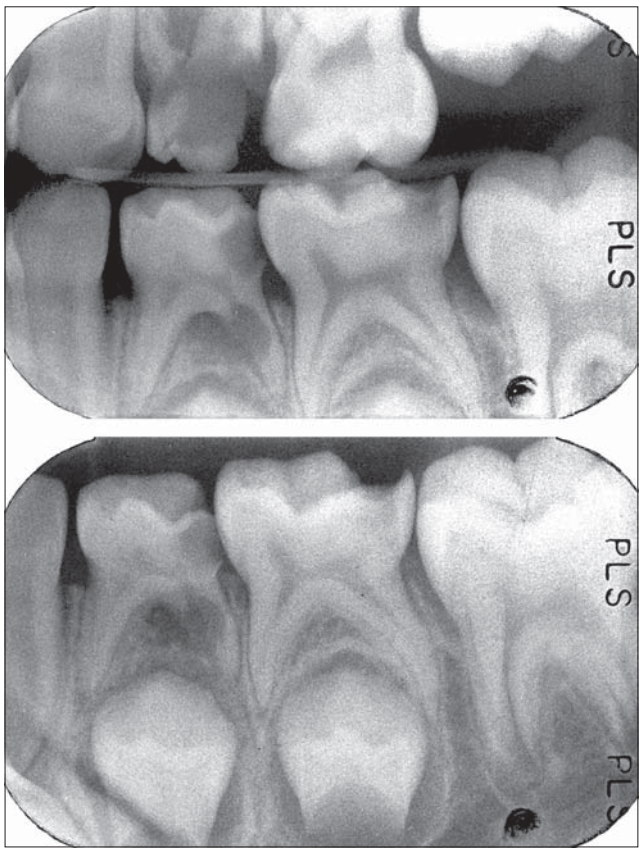

Figure 2a. Case B; preoperative radiographs of an asymptomatic mandibular left second primary molar with deep carious dentin.

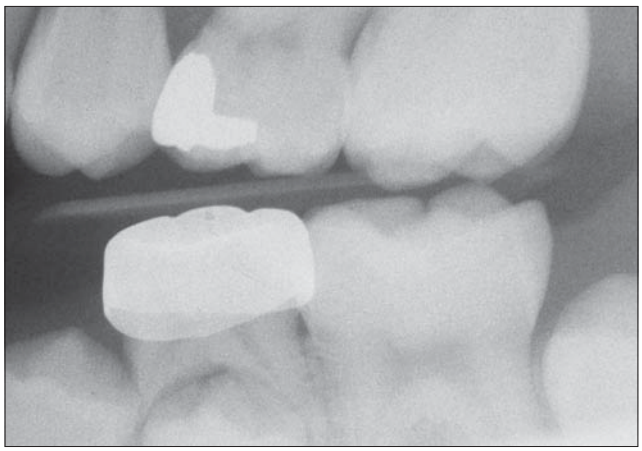

Figure 2b. Case B; a 4-year postoperative bitewing radiograph of an IPT with a SSC from 2a of the mandibular left second primary molar.

3. patients treated between July 1993 through June 1999 (6 years);
4. all teeth met the clinical and radiographic criteria;
5. patients who returned for at least 1 appointment.

Exclusion criteria:

1. primary and permanent anterior teeth;
2. permanent posterior teeth;
3. information in the records was insufficient;
4. patients who never returned for appointments;
5. if the clinician or the assistant failed to record in the patient's chart the term "indirect pulp capping," even though the patient was billed for the service.

Table 1. Location of Failed Teeth

Tooth location in the arch	No. of teeth failed	Success: no. and %	Failure: no. and %	Total
Maxillary first primary molar	3	91 93%	7 7%	98
Mandibular first primary molar	4			
Maxillary second primary molar	1	87 98%	2 2%	89
Mandibular second primary molar	1			

Table 2. Survival Analysis of Pulpal Related Failures

Variable	Likelihood ratio chi-square	Risk ratio*	*P* value
Gender			
Male vs female	0.11	0.8	.74
Age	0.364	0.910	.546
Caries risk			
High vs medium	1.24	0.3682	.264
Operator level			
Grad vs undergrad	0.210	0.733	.649
Tooth type			
First vs second molar	3.99	4.407	.045
Base			
Without vs with	6.729	8.738	.0095
Restoration type			
Amalgam vs SSC	5.274	7.32	.026

*Risk ratio is defined as risk of failure for category 1 of variable vs category 2 (eg, amalgam vs SSC).

The attending pediatric dental faculty made the decision at the recall visits as to the success or a failure of each tooth. All radiographs from treatment through recalls were scored for failure by independent reviewers. A success indicated that the tooth remained clinically and radiographically free of any signs or symptoms of pathology and exfoliated within the normal time. A failure was recorded when the tooth was extracted due to clinical or radiographic pathology such as postoperative pain, swelling, abscess formation, abnormal mobility and internal/external root resorption or periapical/furcation pathology from the radiograph. Premature exfoliation (more than 6 months early) and recurrent caries on the same restorative surfaces of the tooth was also recorded as a failure.

The caries risk assessment for the patients was based on the number of decayed or filled teeth at the time of the IPT treatment appointment. A patient having 3 or more decayed teeth was categorized as high risk, a patient with 2 decayed teeth was placed as medium risk, and if the patient had only one carious lesion or no new lesions over a period of 1 year, the patient was considered to be at low risk of dental caries. According to these criteria, 118 patients were categorized to be at high risk, 14 patients were considered to be at medium risk, and none were considered to be a low-risk patient.

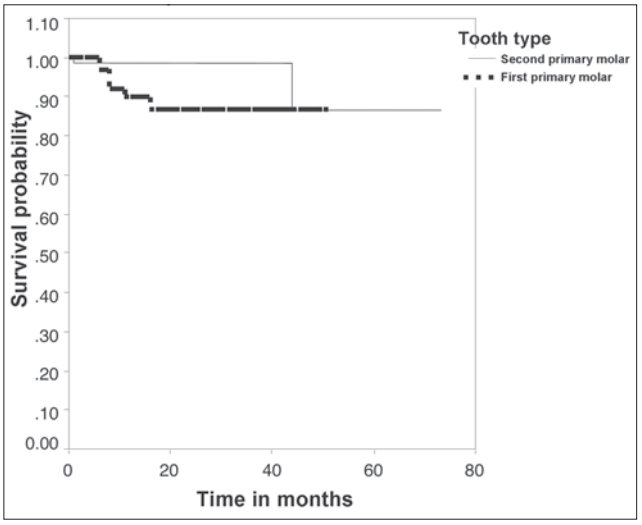

Figure 3. Pulpal failures of IPT between first and second primary molars.

To test the relationship of the failures of IPT to different variables such as age, gender, clinician experience, caries risk, with or without a base, and type of restoration used after IPT, a survival analysis, (Cox proportional hazards model) was performed. A likelihood ratio chi-square test from the Cox proportional hazards model is reported. The analysis was carried out using Statistical Product and Service Solution (SPSS) software (8.0 Window, SPSS International, Chicago, Ill).

Survival analysis was used to more accurately estimate the probability of success by taking into account the varying length of observation time for each tooth. This was done using the SAS procedure, Proc Lifereg (SAS release 8.0 SAS Institute, Cary, NC, 1999).

Results

Baseline

From the 132 patients, 187 primary posterior teeth were treated with indirect pulp treatment. Ninety-eight of these teeth were first primary molars, of which 36 were maxillary (19%) and 62 were mandibular (33%). The remaining 89 teeth were second primary molars, of which 39 were maxillary (21%) and 50 were mandibular (27%).

The age range of the patients was 5 to 13 years with a mean of 8 years and 6 months. Of the 132 patients, 63 (48%) were females and 69 (52%) males.

All the primary molars were lined with calcium hydroxide (Dycal) over the carious dentin left behind. From the 187 teeth, 109 also received a base, of which 91 were based and cemented for a SSC with a zinc oxide eugenol cement (Fynal). The other 18 teeth received a resin modified glass ionomer (Vitrebond) as a base and luting agent for the SSC.

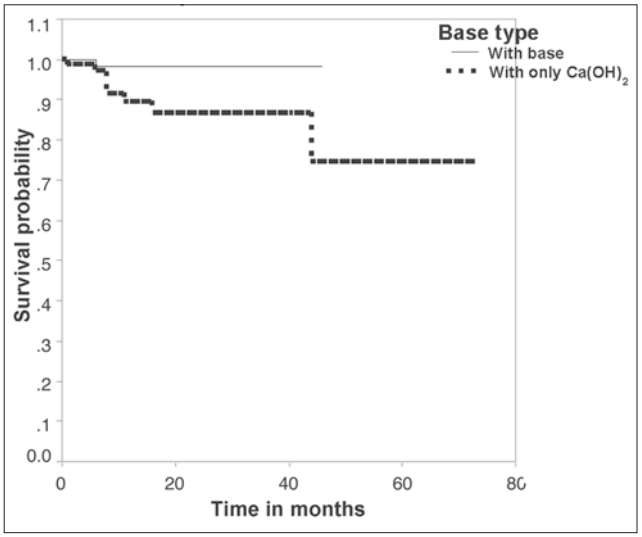

Figure 4. Pulpal failures of IPT between different bases used.

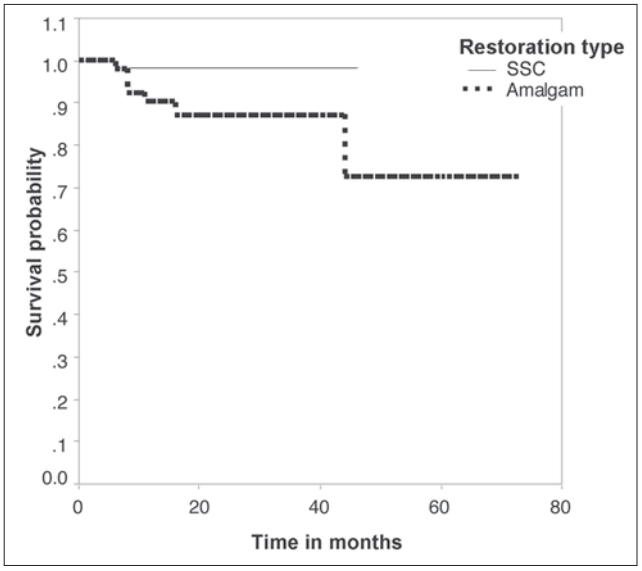

Figure 5. Pulpal failures of IPT between different restorations.

The operators who performed the procedures were pediatric dental residents and third- or fourth-year dental students. Of the 187 teeth, 123 were treated by graduate students and 64 by undergraduate students. All graduate and dental students performed the procedures under the direct supervision of a faculty member in the pediatric dentistry clinics. All procedures were performed under rubber dam isolation.

Teeth were restored with a variety of materials: 68 (36%) by amalgam (Tytin/Kerr); 13 (7%) by composite (Z-200, 3M); 4 (2%) by a resin modified glass ionomer (RMGI); 101 (54%) by stainless steel crowns (SSC); and only 1 (1%) tooth restored with a zinc phosphate cement.

One hundred eighty-seven teeth were followed for a period ranging from 2 weeks to 73 months: 64 teeth were followed for a period ranging from 2 weeks to 6 months (34%); 38 for 6 to 12 months (20%), 22 for 12 to 18 months (12%); 16 for 18 to 24 months (9%); 25 for 24 to 36 months (13%); and 22 teeth for over 36 months (12%). Of the 187 teeth, only 9 teeth failed (5%).

Survival analysis methods were used to analyze data because the strength of the methodology lies in the fact that all follow-up data points can be used in the analysis.

The survival probability for 1 year was estimated to be 96%, with a 95% confidence interval of 93% to 98%, using an exponential survival model. This model assumes that the hazard rate was constant over time. The chi-square test for the appropriateness of this distribution was not significant (chi-square=0.1351; df=1; *P*=.7132).

Clinically, 2 teeth had recurrent caries, 4 had fractured restorations beyond repair, and 1 had continuous pain. Radiographically, 3 teeth showed furcation and periapical radiolucency, 2 teeth had a defective restoration and recurrent caries, 2 teeth had a defective restoration, 1 tooth had recurrent caries around the area treated by indirect pulp treatment, and 1 tooth had no radiographic film. Out of the 9 teeth, 6 were extracted, 2 were pulpotomized, and 1 had no treatment provided.

The location of the failed teeth in the mouth is as follows (Table 1); 3 teeth were maxillary first primary molars (33% of the total failures), 4 were mandibular first primary molars (44%), 1 tooth was a maxillary second primary molar (11%), and 1 was a mandibular second primary molar (11%).

Survival analysis allowed comparison of the survival of each tooth treated by IPT for the different variables regardless of the length of time the tooth was followed. Survival analysis showed no significant relation between the success of IPT with age, caries risk, or the level of experience of the operators (Table 2).

The location of the teeth in the dental arch played a significant role in the success of IPT. Survival analysis results show a significant difference between the success of IPT on primary first molars compared to second primary molars (*P*=.045). The first primary molar was 4.4 times more likely to fail than the second primary molar (Table 2, Figure 3).

Calcium hydroxide was used as a liner over all IPT performed. From the 187 teeth, 78 received only the liner with no base material as a protection. Eight of the 9 failures were among these teeth (89% of the total failures). Ninety-one teeth used Fynal as a luting plus base, and only 1 tooth failed. None of the 18 teeth treated by the RMGI luting plus base failed. For our analysis, Fynal and the RMGI were combined. There was a significant difference in the success of IPT with the use of a base compared to the teeth treated with no base used (*P*=.009). Teeth without a base, were 8.7 times more likely to fail compared to the teeth treated with a base (Table 2, Figure 4).

Sixty-eight teeth were restored with amalgam, 1 was restored with zinc phosphate, 13 with composite, 4 with resin modified glass ionomer, and 101 teeth with stainless steel crowns. Seven out of the 68 teeth treated with an amalgam failed. The only tooth treated with zinc phosphate failed, and only one of the 101 teeth restored by SSC failed.

The result shows a significant superiority of SSC over amalgam in the success of IPT (P=.026). Amalgam was 7.7 times more likely to fail compared to SSC (Table 2, Figure 5). The other restorative materials (glass ionomer and composite) were not included in the survival analysis because the teeth treated with those materials were few in number.

A total of 12 teeth had exfoliated by the end of the study. Nine of these teeth exfoliated simultaneously with the contralateral side. One tooth exfoliated after the contralateral side, and 2 teeth exfoliated before the contralateral side of the same arch, but each exfoliated within 6 months of the contralateral tooth.

Discussion

The results of this retrospective study agree with results of other studies conducted to verify the clinical success of IPT.[10,16,24,31-33] The proportion of teeth that survived without failure was 95% (178 of the 187 teeth survived). Survival analysis was also used to estimate more accurately the probability of success, taking into account the varying lengths of follow-up for each tooth. Survival analysis is a robust statistical method that allows for analysis of all follow-up, therefore, no data are lost. The probability of survival for one year was estimated to be 96% (95% confidence interval=93%-98%).

Retrospective studies with numerous operators, such as this study, cannot control adequately all decision criteria for patient care. Therefore, unknown factors related to patient or treatment variables may influence the data.

There were several factors associated with the failure of IPT. One of these variables was the tooth location in the dental arch. First primary molars treated by IPT were significantly more likely to fail than second primary molars. These results were very similar to those reported by Sveen in 1969. He reported that first primary molars, specifically the maxillary, failed more often than second primary molars when treated with IPT.[35] Farooq (2000) found that mandibular first molars tend to fail more often than the second primary molars when treated by a pulpotomy.[31] This difference in failures is probably due to the root anatomy, size, and restorability of the first primary molars.

Another factor that influenced the success of IPT was the restorative material used after the IPT procedure. Most of the failures were among teeth restored with an amalgam restoration (77% of the total failures). Only 1 tooth treated by a SSC failed, and none of the teeth treated by a composite restoration failed. Three out of 7 teeth restored by amalgam failed due to fracture or a lost restoration leading to pulpal pathology. Thus, the proper choice of the restorative material will affect the success of IPT (amalgam is 7.7 times more likely to fail than SSC). The best alternative to intracoronal, multisurface restorations is a SSC. The SSC restoration has consistently been reported to be more durable than other restorations in the primary dentition.[36-39] In 1981, Dawson reported that the average lifespan of a SSC on first primary molars was 40 months and 38 months for second primary molars, whereas the lifespan for amalgam was 23 months on first primary molars and 28 months for the second primary molars.[37] In this study, one cannot comment on the success of composite restorations used after an IPT because of the limited number of teeth treated.

The authors' results showed that teeth treated with IPT, lined by $Ca(OH)_2$, and then based by a RMGI or zinc oxide eugenol (ZOE) were significantly more successful than teeth treated with only a calcium hydroxide liner. Eight out of the 9 teeth that failed were treated without the use of a base. The authors speculate that a base may offer thermal insulation, hardness, and a proper seal to prevent leakage. Traditionally, in the 1960s and 1970s, both ZOE and $Ca(OH)_2$ were used as a liner/base over IPT. Many studies showed that both ZOE and $Ca(OH)_2$ were effective in promoting reparative dentin as well as having the ability to sterilize the remaining carious lesion.[7,10,16,17,24-28] Recently, both self-cure glass ionomer as well as RMGI were introduced to be used as a liner or base. A glass ionomer forms hydrogen bonds to dentin compared to the acid-etched hybrid layer of a composite. Research has shown that Vitrebond, a RMGI, has antimicrobial properties that complement its sealing ability in protecting against bacterial access to dentinal tubules.[40-44] Clinical evidence of RMGI promoting reparative dentin has not been reported. Thus, the use of $Ca(OH)_2$ as a liner before applying a RMGI may still be necessary to gain all the essential properties. It is interesting that Farooq (2000) reported 93% success of IPT over an average of 4 years with the use of a RMGI as a liner or base without the use of a liner of $Ca(OH)_2$.[31] Falster reported 90% results for 2 years using either a $Ca(OH)_2$ liner or only an adhesive resin system.[33] Thus, the question of the need for a liner of $Ca(OH)_2$ with IPT is still unanswered, but the success of an IPT is very favorable.

From this study, age, gender, caries-risk assessment, and the level of the experience of the operator had no significant effect on the success of an IPT. The authors had expected that clinicians with more experience would have more success. The only explanation is that all the clinicians were trained at the same school, and all were working under direct supervision of the pediatric dentist faculty. In addition, it seems that the teeth treated with IPT were properly selected. Therefore, an IPT performed on a primary molar is equally successful, regardless of the experience of the operator.

Finally, the literature now contains several reported studies stating a higher success rate with IPT than with a pulpotomy treatment.[24,31-33] A careful diagnosis plus appropriate removal of the caries from the lateral walls—therefore, leaving deep carious dentin to avoid a microscopic exposure—along with the use of bonding agents, achieves a high success with IPT for primary molars.

Conclusions

1. The overall proportion of the success of indirect pulp treatment in primary posterior teeth was 95% (178/187 teeth). The 1-year probability of survival of each tooth was estimated to be 96%, using an exponential survival model.
2. The use of a base to cover the remaining carious dentin significantly increased the success of IPT.
3. The use of the SSC showed significantly higher success than the use of amalgam when an IPT was performed. The proper selection of a restorative material significantly affects the success of an IPT since restoration leakage or fracture can lead to pulpal failure.
4. Primary first molars failed more frequently than second primary molars.
5. Gender, age, caries risk, and operator's skill and experience had no significant effect on the success of IPT.
6. IPT should be considered as an alternative treatment to pulpotomy in the treatment of deep dental caries in teeth without signs of pulpal degeneration.

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Abstract of the Scientific Literature

Linear Cephalometrics in European Americans and African Americans

One of the shortcomings and confounders of cephalometric studies is radiographic enlargement. The goal of this study was to eliminate this factor and make comparisons under strict enlargement correction guidelines using measurements from 4 key cephalometric data resources. As one of the sources contained data on Americans of African descent, this study compared and contrasted each data set and also ethnic groups. Using data from studies conducted in Ann Arbor, Cleveland, Philadelphia, and Nashville, linear correction was applied to each data set, and 11 cephalometric measurements were presented graphically. Descriptive results show corrected sella-nasion lengths to be more comparable than previously presented and lower facial height as the most variable characteristic between all groups. The Nashville cohort had the largest values for total face height, lower face height, posterior face height, mandibular diagonal and corpus lengths, and Y-axis. Total and lower facial height was lowest for the Cleveland group, and maxillary length was lowest in the subjects from Philadelphia. The results of the study suggest possible skeletal differences between the 2 racial groups and to a lesser extent, between data sets.

Comments: This descriptive study reviews longstanding data and supports the need for race-specific cephalometric norms. **AW**

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Dibbets JMH, Nolte K. Comparison of linear cephalometric dimensions in Americans of European descent (Ann Arbor, Cleveland, Philadelphia) and Americans of African descent (Nashville). *Angle Orthod.* 2002;72:324-330.

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