



Predicting pulpectomy success and its relationship to exfoliation and succedaneous dentition

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Abstract

This study evaluated factors that affected pulpectomy (PE) success and its effect on the succedaneous tooth's eruption and enamel formation. Sixty-five of 250 patients with PEs met the selection criteria and yielded 81 zinc oxide-eugenol PEs (30 incisors, 51 molars) followed a mean time of 90.8 months. Overall PE success was 77.7% with no difference between molars and incisors ($P = 0.53$). Enamel defects were observed in 18.7% of succedaneous teeth and were related ($P = 0.005$) to the pre-existing infection causing excess root resorption (> 1 mm preoperative root resorption = 44.4% defects) but were not related to overretention of ZOE filler ($P = 1$) or length of fill ($P = 0.36$). The PE procedure was not related to causing succedaneous tooth defects since teeth replacing PEs showed no significant increase in the incidence of defects compared with untreated contralateral controls ($P = 0.99$). There was a 20% incidence of succedaneous tooth anterior cross-bite or palatal eruption following incisor PEs and 21.6% ectopic eruption of premolars following primary molar PEs. Most PEs (95.9%) were lost at their normal exfoliation time or earlier, but 35.8% needed extraction due to overretention by soft tissue at the time of shedding.

*Pulpectomy success rates showed that the most important preoperative predictor was the amount of primary tooth root resorption. Greater than 1 mm of root resorption resulted in only a 23.1% success rate, which was significant ($P = 0.001$). Pulpectomies filled short or to the apex had a significantly greater success ($P = 0.011$) than long fills. Pulpectomies correctly done do not appear to contribute to adverse effects on succedaneous tooth formation but have a 20% chance of altering the path of permanent tooth eruption. (*Pediatr Dent* 18:57-63, 1996)*

The use of zinc oxide and eugenol (ZOE) to fill root canals of primary teeth was described by Sweet¹ in 1930. Since the 1930s, other authors have advocated the use of ZOE to fill the canals of primary teeth needing root canal therapy.^{2,3} In 1967, it was

shown that ZOE set in a dense mass resisted resorption and was very irritating to the periapical tissues in rats.⁴

The first reported one-visit pulpectomy (PE) study was in 1972 on 39 primary molars filled with ZOE.⁵ After an average followup of 16 months, 35 of 39 molars were successful but no mention of ZOE resorption or defects in the succedaneous molars was made. In 1979, it was speculated that the resorption rate of ZOE and the root differed, resulting in small areas of ZOE paste possibly being retained.⁶ One report found a correlation between formocresol pulpotomies in primary teeth and enamel defects in the succedaneous teeth.⁷ Others indicated that pulpal inflammation that existed prior to pulp therapy was the likely cause of enamel defects in succedaneous teeth.^{8,9} A radiographic study involving 339 children age 9-12 years found no relationship between primary teeth with extensive caries and succedaneous tooth enamel defects.¹⁰ A case report was presented of arrested tooth formation in a mandibular second premolar after ZOE was extruded out the apex of the primary second molar PE.¹¹ In 1991, iodoform paste was advocated as a PE filler in primary teeth due to its resorbability and disinfectant properties.¹² Those authors felt ZOE resisted resorption and might deflect the path of eruption of the succedaneous tooth.

To date, the long-term followup PE studies¹³⁻¹⁹ have not investigated whether primary tooth PEs alter the path of the permanent tooth's eruption. None has determined if PEs result in a higher incidence of enamel defects in the permanent teeth. In a 1992 report of 117 permanent incisors, 29 had a history of incisor trauma and ZOE pulpectomy treatment.²⁰ The incidence of enamel defects was 2 to 3 times greater in the permanent incisors that replaced the pulpectomized incisors than in controls.

The purpose of this study was to evaluate the long-term success of PE procedures on primary teeth, to determine the factors that influence success or failure of the procedure, and to determine whether PEs were associated with enamel defects or altered eruption of succedaneous teeth.

Methods and materials

A review of all the dental records (> 6000 patients) of a pediatric dental practice yielded 250 patients who had one or more ZOE primary tooth PEs. Their charts were further reviewed to ascertain those teeth with ZOE PEs that either exfoliated or were extracted and replaced by the succedaneous tooth. To be included in this study, only patients with a PE in which the primary tooth showed preoperative radiographic and/or clinical signs of irreversible pulpitis were included (i.e. bifurcation radiolucency, pathologic root resorption, dry necrotic pulp, or fistula). The pulpectomized teeth met three criteria: 1) a preoperative and two or more postoperative radiographs existed to assess the PE success; 2) the pulpectomized tooth was extracted or had exfoliated, and the succedaneous tooth had erupted; 3) a radiograph was available of the succedaneous tooth.

Criteria for pulpectomy success

Consent to expose the needed radiographs was obtained after risks and benefits were discussed. Pulpectomy success was based on the last tooth assessment of a tooth satisfying all the following criteria:

Clinical criteria

1. No gingival swelling or sinus tract 6 months or more postoperatively.
2. No purulent exudate expressed from the gingival margin

3. No abnormal mobility other than mobility from normal exfoliation
4. No pain on postoperative checkup.

Radiographic criteria

1. No pathologic signs of external root resorption or continued resorption if any was present preoperatively
2. A bifurcation radiolucency resolved 6–12 months postoperatively
3. No periapical radiolucency formation postoperatively.

The pulpectomized teeth were evaluated for preoperative apical root resorption and adequacy of endodontic fill. Preoperative root resorption was categorized as follows: 1) no root resorption, defined as a root showing no evidence of preoperative apical root resorption; 2) minimal resorption, meaning the root(s) had incipient root resorption of 1 mm or less at the apex; 3) excess resorption, which was any root or part of a root with obvious apical root resorption of > 1 mm (Fig 1a). These assessments were made by comparing the tooth's root(s) to adjacent and/or contralateral teeth, while a molar's roots also were compared to one another. The adequacy of the endodontic fill was recorded from the immediate post-fill radiograph as being short, complete, or long. For incisors, a short fill was defined as a case where the ZOE ended 1 mm or more short of the apex, a complete fill appeared to have ZOE end at the radiographic apex, and a long fill had ZOE

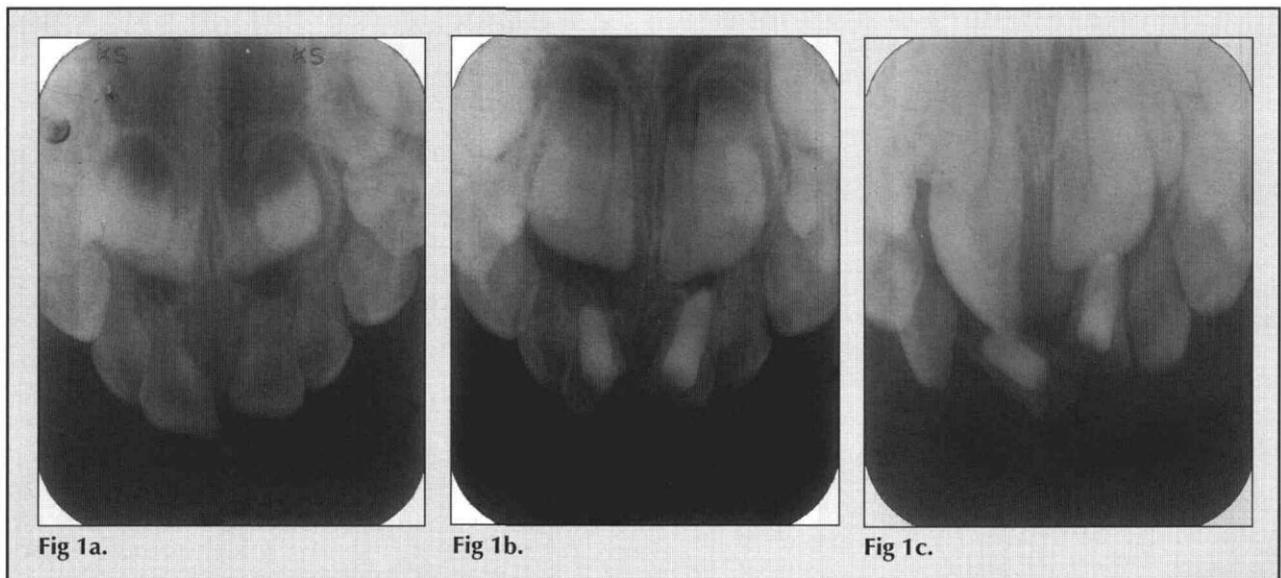


Fig 1a. Preoperative facial radiograph of two central incisors with necrotic pulps. Note the normal position of the two permanent central incisors. Patient was age 33 months and had traumatized the teeth 1 year before. Both incisors were judged to have excess (> 1 mm) preoperative root resorption. **Fig 1b.** An 18-month postoperative radiograph of the same patient's incisor PEs. The maxillary left PE incisor was judged a success and filled to the apex. The maxillary right incisor was judged a short fill and was a failure. **Fig 1c.** The same patient's radiograph at age 7 1/2 years. Note that the permanent right central incisor was erupting ectopically to the palatal aspect of the overretained but very loose primary right central incisor. Both PE teeth were extracted. The central incisors erupted into normal positions after minor orthodontic treatment.

extruded past the radiographic apex. For molars, a short fill meant all the canals were filled 1 mm or more short of the apex, a complete fill had one or more of the canals having ZOE ending at the radiographic apex, and a long fill meant any molar canal showing ZOE outside the root. A Boley gauge was used when necessary to categorize the length of fill and amount of preoperative root resorption.

Prior to rating any of the pulpectomies, the two authors standardized their evaluation technique by analyzing five pulpectomies not included in the study. The evaluation consisted of each author reviewing the chart's treatment notes and all of the preoperative and postoperative radiographs and photographs. Tooth ratings for each category were made and then compared. There was over 90% agreement. Cases in which the ratings differed, were discussed until mutual agreement was reached or the lower of the two rankings was given.

Following PE tooth loss, the alveolar area was examined radiographically for signs of retained ZOE. Radiographs showing evidence of radiopaque material in the region of the succedaneous tooth were categorized as having retained ZOE filler. The ZOE was judged as completely resorbed if no radiopaque material was noted by either author.

When a PE tooth was lost by exfoliation or extraction, its loss was categorized as being early, late, or at the expected time. This assessment was based on the dates of radiographs and chart entries nearest to the time of tooth loss within a 6-month recall visit. For patients who did not return regularly, tooth loss timing was not made. The minimum postoperative followup was 6 months. Comparisons were made to the contralateral tooth if untreated, and the eruption timing of the other adjacent and opposing teeth. If the PE tooth was lost 6 or more months earlier than an untreated antimere and/or other adjacent teeth, its loss was rated as early. Using the same criteria, if the PE was lost 6 or more months later, its loss was rated as late. The loss of all other PE teeth were grouped as at their expected time. The reason for a tooth's loss was categorized as follows: 1) exfoliation, 2) extraction because of PE failure or infection, or 3) extraction when PE tooth was overretained and the permanent tooth was erupting from clinical or radiographic examination.

Enamel defects involving white opacities, yellow areas of demineralization, or surface irregularities on the succedaneous teeth replacing a PE as well as the contralateral tooth were recorded. The group of contralateral teeth that did not have a PE, a pulpotomy, and had not been extracted were termed untreated controls. Either the patient was examined, a photograph of the succedaneous tooth was available, or the patient's chart had adequate entries describing the presence or absence of enamel defects in the succedaneous teeth. The location and nature of the defects were noted. The incidence of anterior cross-bites and/or ectopic eruption of the succedaneous tooth was tabulated.

Chi-square analysis with a significance level ≤ 0.05 were employed.

Results

More than 6000 records were screened, and 65 patients (33 males and 32 females) with 81 PEs provided the data for the study. The ZOE PEs were in 30 incisors (26 centrals and four laterals) and 51 molars (16 mandibular first, 16 mandibular second, 14 maxillary first, and five maxillary second molars). One of the authors (JAC) placed 77 of the PEs and another pediatric dentist did the remaining four. At the time of treatment, the children ranged in age from 19 to 111 months (mean age = 52.2 months). All the PEs were done with a thick paste as described by Coll et al.¹³ without formocresol in the USP formulary ZOE filler.

Succedaneous tooth enamel defects results

Enamel defects were observed in 18.7% (14/75) of the succedaneous teeth. The incidence of enamel defects in the succedaneous tooth was related ($P = 0.005$) to the amount of preoperative root resorption (Table 1). There was a 44.4% chance of finding an enamel defect on the succedaneous tooth if the PE tooth had excessive (> 1 mm) preoperative root resorption, a 23.1%

TABLE 1. SUCCEDANEUS TOOTH ENAMEL DEFECTS

| Variable* | Percentage of Enamel Defects | P-Value† |
|--|------------------------------|------------------------------------|
| Preoperative root resorption | | |
| None | 1/28 (3.6%) | Sig. $\chi_2 = 10.96$ DF = 2 |
| Minimal | 6/26 (23.1%) | |
| Excessive | 4/9 (44.4%) | |
| ZOE retained | 5/32 (15.6%) | NS |
| ZOE not retained | 6/32 (18.8%) | |
| Pulpectomy length of fill | | |
| Short | 6/35 (17.1%) | NS |
| Complete | 1/16 (6.3%) | |
| Long | 4/16 (25.0%) | |
| Pulpectomy success | 7/55 (12.7%) | NS |
| Pulpectomy failure | 4/12 (33.3%) | |
| Presence of defects in teeth replacing | | |
| Pulpectomies | 14/75 (18.7%) | NS |
| Contralateral tooth | 12/65 (18.5%) | |
| Presence of defects in teeth replacing | | |
| Pulpectomies | 5/33 (15.2%) | NS |
| Untreated contralateral controls | 6/33 (18.2%) | |
| Incisors treated due to: | | |
| Trauma | 3/9 (33.3%) | NS |
| Caries | 4/21 (19.1%) | |

* For each grouping of variables, not all teeth were available for each analysis.

† Significance level $P = 0.05$.

chance if there was minimal (0–1 mm) preoperative resorption, but only 3.6% chance if the tooth had no preoperative root resorption. Eleven of these 14 defects were small, white enamel opacities or small cuspal or buccal defects that required no treatment. The other three teeth required restorations for brown hypoplastic defects.

The presence of enamel defects on the succedaneous tooth was not related ($P = 1$) to retention of the ZOE filler paste (Table 1), with almost identical percentages of enamel defects in the ZOE retained and not retained groups (15.6 versus 18.8% respectively). The presence of enamel defects also was not related to the length of ZOE fill ($P = 0.36$) or PE success ($P = 0.19$; Table 1).

The incidence of enamel defects was not significantly different ($P = 0.99$) in the succedaneous teeth that replaced pulpectomies versus the succedaneous contralateral teeth (Table 1). There was an 18.7% (14/75) incidence of enamel defects in the teeth that replaced PEs, while the contralateral succedaneous teeth had an incidence of 18.5% (12/65). In 33 patients, the PE had an untreated control. In these patients, 15.2% (5/33) of the PE tooth's succedaneous teeth had enamel defects while the contralateral untreated controls had 18.2% (6/33). There was no significant difference between these frequencies ($P = 0.99$; Table 1).

In the 30 succedaneous incisors, the incidence of enamel defects was 23.3% (7/30). The incidence of enamel defects in these incisors was not significantly different ($P = 0.99$) if the primary incisor was treated because of trauma or caries (Table 1). There were 28 PE incisors with data on their amount of preoperative root resorption. All enamel defects in succedaneous incisors occurred in those that replaced PEs with minimal or excess preoperative root resorption ($N = 16$). No defects were found in teeth that replaced primary incisors rated as having no preoperative root resorption ($N = 12$).

Pulpectomy success results

The success rate of pulpectomies was related ($P = 0.001$) to the amount of preoperative root resorption (Table 2). Pulpectomies that had no preoperative root resorption had a success rate of 91.7% (33/36). Those rated as having minimal preoperative root resorption had a success rate of 82.8% (24/29). Those with excessive preoperative root resorption had a success rate of 23.1% (3/13). Whether PE teeth were lost normally, early, or late was not related significantly to the PE success rate ($P = 0.18$; Table 2). The PE success rate also was not related to whether ZOE filler was retained after exfoliation or not ($P = 0.11$; Table 2).

The overall PE success rate was 77.8% (63/81). Molar success was 74.5% (38/51) and incisor success was 83.3% (25/30), which were not significantly different ($P = 0.53$; Table 2). These patients were followed a mean time of 90.8 months (range = 20–177 months). The age of the patient at treatment time was not related significantly to the PE success rate ($P = 0.86$ incisors; $P = 0.74$ molars; Table 2).

TABLE 2. FACTORS AFFECTING PULPECTOMY SUCCESS

| Variable* | Pulpectomy Success | P-Value† |
|------------------------------|--------------------|-----------------------------------|
| Preoperative root resorption | | |
| None | 33/36 (91.7%) | Sig. $\chi_2 = 26.2$ DF = 2 |
| Minimal < 1 mm | 24/29 (82.8%) | |
| Excessive > 1 mm | 3/13 (23.1%) | |
| Pulpectomy lost | | |
| Early/late | 23/35 (65.7%) | NS |
| Normally | 32/39 (82.1%) | |
| ZOE retained | 33/60 (55.0%) | NS |
| No ZOE retained | 27/60 (45.0%) | |
| Molars | 38/51 (74.5%) | NS |
| Incisors | 25/30 (83.3%) | |
| Incisors | | |
| Patient age \leq 36 months | 17/20 (85.0%) | NS |
| Patient age \geq 37 months | 8/10 (80.0%) | |
| Molars | | |
| Patient age \leq 36 months | 9/12 (75.0%) | NS |
| Patient age \geq 37 months | 29/39 (74.4%) | |
| Length of fill | | |
| Short | 32/37 (86.5%) | Sig. $\chi_2 = 8.98$ DF = 2 |
| Complete | 16/18 (88.9%) | |
| Long | 15/26 (57.7%) | |
| Pulpectomy exfoliated | 44/51 (86.3%) | Sig. $\chi_2 = 4.9$ DF = 1 |
| Pulpectomy extracted | 18/29 (62.1%) | |

* For each grouping of variables, not all the teeth were available for each analysis.

† Significance level $P = 0.05$.

ZOE PE success rate was related significantly to the length of the root canal filling. Success rate for short fills was 86.5% (32/37) and for those filled to the apex was 88.9% (16/18). These two were significantly greater ($P = 0.011$) than the success rate of long fills, which was 57.7% (15/26) in Table 2. The length of the ZOE fill approached statistical significance when compared with the amount of preoperative root resorption ($P = 0.054$). Teeth with excessive root resorption had 53.8% (7/13) with long fills, while those teeth with no preoperative root resorption had 16.7% (6/36) with long fills. Pulpectomies that exfoliated had a statistically significant increase in their rate of success (86.3%) versus those that were extracted (62.1%; Table 2).

Pulpectomy tooth loss results

The timing of the PE tooth's loss showed 52.7% (39/74) were lost at their expected shedding time. There were 43.2% (32/74) lost 6 or more months early, while 4.1% (3/74) were lost 6 or more months later than normal. The reasons for the PE tooth's loss are presented in Table 3. There were 64.2% (52/81) that exfoliated and 6.2% (5/81) that were extracted due to infection. In

addition, 29.6% (24/81) were extracted because they were loose but over retained when the permanent tooth was erupting. There was no significant difference between incisors and molars in the rate of teeth that exfoliated versus those that were extracted ($P = 0.17$). Whether ZOE was retained or not was not statistically different in the extracted or the exfoliated teeth ($P = 0.75$). There were 24 PEs that were categorized as having been overretained and extracted, with an equal distribution (50%) having retained their ZOE filler. The 24 overretained teeth had only 8.3% (2/24) rated as having been lost late, while 54.2% (13/24) were lost at their expected time, and 37.5% (9/24) were lost early.

There was a 20% (6/30) incidence of anterior cross bites or palatal eruption in the 30 succedaneous incisors that replaced the PE incisors (Fig 1a-c). The other 80% (24/30) erupted into their normal position. For the 51 PE molars, 21.6% (11/51) were extracted as a result of over retention with ectopic eruption of the succedaneous tooth, and the remaining cases erupted normally.

TABLE 3. REASONS FOR PULPECTOMY TOOTH LOSS

| Type of Tooth | Exfoliation | Extraction Infection | Extraction Over-retained | Total |
|---------------|-------------|----------------------|--------------------------|-------|
| Incisors | 16 (53.3%) | 1 (3.3%) | 13 (43.3%) | 30 |
| Molars | 36 (70.6%) | 4 (7.8%) | 11 (21.6%) | 51 |
| Totals | 52 (64.2%) | 5 (6.2%) | 24 (29.6%) | 81 |

Discussion

This study's design had the inherent limitations of any retrospective study. Assessment of root resorption, the variable length of follow-up, timing of tooth exfoliation, and trauma diagnosis could lead to different interpretations. In the 81 teeth, there were few cases where categorizing the tooth was not obvious to the authors. Eighty percent of the teeth reported in this study were included in previous reports.^{13, 14}

Succedaneous tooth enamel defects

Enamel defects appeared to result from the infection existing before the PE procedure and not the pulpectomy procedure itself. The data showed that the incidence of enamel defects in succedaneous teeth increased as the amount of preoperative primary tooth root resorption increased. Excess preoperative root resorption may indicate teeth with extensive pre-existing infection in the periradicular area had the potential to harm the permanent tooth before the pulpectomy was ever performed. This contradicts Pruhs et al.⁷ who contended pulpotomy procedures caused defects in succedaneous teeth.

The strongest evidence that the PE procedure itself did not cause the succedaneous tooth enamel defects was the data on untreated contralateral controls (Table 1). If the pulpectomy procedure was the source of enamel defects in succedaneous teeth, the 33 untreated contralateral controls should have had fewer defects.

The data showed no significant difference in enamel defect occurrence in teeth replacing PEs versus those replacing untreated controls.

The data suggested that a pre-existing infection would not likely be resolved by a pulpectomy procedure in a case of excess preoperative root resorption. In such cases, the chance of PE failure was 76.9%, and the occurrence of a succedaneous tooth defect 44.4%. Extraction should be the treatment of choice in these cases to quickly eliminate the infection unless a tooth's retention is more important to preserve the arch's integrity (i.e. a second primary molar prior to eruption of the first permanent molar).

Long fills were not related statistically to the occurrence of enamel defects on succedaneous teeth. In all but three cases, the ZOE fill was not close to the developing tooth. In those three PEs, there was extensive preoperative root resorption and a long fill approximating the developing tooth's crypt. It was only in these three cases that the succedaneous teeth developed enamel defects that required restorations. This finding was similar to the case report of Jerrell and Ronk.¹¹

Holan et al.²⁰ found a 2 to 3 times higher incidence of enamel defects compared with controls in the succedaneous incisors that replaced traumatized primary incisors treated with ZOE PEs. Our study contradicts their findings since the 30 PE incisors had no significant difference in enamel defect occurrence versus the controls. This contradiction may be because Holan et al. did not investigate the factor of preoperative root resorption. If their PE teeth had significantly more preoperative root resorption than the controls, this could have resulted in the 2-3 times higher incidence of enamel defects they reported.

The trauma history was not related to the occurrence of enamel defects in the PE incisors reported here. None of the traumatized incisors was severely displaced or intruded. All had darkened after trauma and formed a fistula. Severely displaced or intruded teeth may not show comparable findings concerning defects in succedaneous teeth. Of the 28 PE incisors with data on preoperative root resorption, 42.9% had no resorption, 35.7% had minimal resorption, and 21.4% had excess root resorption. No enamel defects were found in succedaneous teeth that replaced the group of incisors having no preoperative root resorption.

Pulpectomy success

The success of ZOE PEs was related significantly to the amount of preoperative root resorption. Primary teeth with minimal or no preoperative root resorption had significantly higher PE success than those with excessive (> 1 mm) resorption. This finding confirmed what the other PE studies¹³⁻¹⁷ had indicated. Excessive root resorption likely made it difficult to resolve the periapical infection with the PE procedure. The amount of preoperative root resorption seems to be the most important radiographic diagnostic criterion in determining whether a PE will likely succeed.

The molar pulpectomy success was lower but not significantly different from the incisor rate. The slightly lower molar success was likely due to four pulpectomized second primary molars with excessive root resorption that were saved for about 1 year until the first permanent molar erupted. All failed and were extracted. There were no comparably treated incisors. If these four molars are removed from the data, the resulting molar success rate is 80.9% (38/47).

PE success also was related to the length of the ZOE fill. Success rates for short fills 1 mm or more short of the apex and those ending at the apex were significantly greater than long fills. The data approached significance ($P=0.054$) in showing teeth with pre-existing excess root resorption resulted in PEs with long fills. Garcia-Godoy¹⁷ indicated it was acceptable to extrude iodoform paste past the apex since it resorbed in two weeks, but did not correlate success to length of fill. Barr et al.¹⁶ rated 88.7% of the 62 ZOE pulpectomized molars as being filled acceptably, which was within 2 mm of the apex. They did not correlate that to success rates. Sadrian and Coll²¹ found that when ZOE was retained after PE loss, it resorbed with time and was not associated with any pathology nor PE success. Yacobi et al.¹⁹ reported that underfilled canals failed significantly more than those filled completely in vital teeth with carious exposures after a 12-month followup. They did not adequately define their categories of ZOE fill and their long-term findings are yet unknown.

PE success also was compared to other factors. The teeth with PEs that exfoliated were statistically more successful ($P = 0.03$) than those that were extracted. This result was expected since teeth with failed PEs would likely have been extracted and ones that were successful were left to exfoliate. Retention of ZOE filler particles was not statistically related to PE success. This may be due to failed PEs having a chronic infection in the periradicular area that resorbed ZOE, duplicating the ZOE resorption process in successful PEs. PE success rate was not related significantly to the timing of the tooth's loss ($P = 0.18$) nor the age of the patient at treatment time.

Pulpectomy tooth loss

Twenty percent of the PE incisors were extracted when the permanent incisor was erupting palatally or into cross-bite, and 21.6% (11/51) of the molars were extracted because of ectopic eruption of the succedaneous premolar. This incidence of eruption problems seemed high. The reported incidence of incisor anterior cross-bite usually is combined with posterior cross-bite.²² Rule and Gibberman²³ reported a 13.8% incidence of all types of cross-bites in 560 children age 6–13, but only 4.1% were incisor cross-bites. In addition, they noted ectopic eruption and retained primary teeth in 4.4% of the patients. ZOE PEs may interfere with the eruption path of some permanent teeth.

There was a tendency for teeth with successful PEs to be lost at their normal time or earlier than normal,

yet many had to be extracted. This finding is similar to that of Loevy who reported that premolars erupt early after primary tooth pulpotomies.²⁴ Molars and incisors were not significantly different in this regard ($P = 0.17$). This phenomenon was not related ($P = 0.75$) to retention of ZOE filler particles after tooth loss. Possibly a mild chronic inflammation exists in the periapical area of some PEs judged successful that is not clinically evident. This could cause the premature eruption of the succedaneous tooth and uneven root resorption of the PE. The resulting condition would be a successful PE over retained by soft tissue. Many of the teeth with successful PEs were loose but still retained by soft tissue with the patient unable to exfoliate the tooth. This was similar to the difficulty some children have shedding a necrotic primary incisor that never had pulpal treatment.

Ranly and Garcia-Godoy¹² speculated ZOE resisted resorption and could deflect the path of eruption of the succedaneous tooth. Flaitz et al.,¹⁵ observed deflections of the permanent tooth bud in 20% of the incisor PEs. They speculated this finding was due to pretreatment trauma or incomplete resorption of the hardened ZOE. Trauma seems an unlikely reason since 20% of our study's incisors and premolars erupted ectopically and trauma to the primary molars was unlikely. Unresolved periapical infections or thick plugs of filler paste that resist resorption seem a more likely cause of ectopic eruption of succedaneous teeth.

The only time a PE is indicated in a primary tooth with excessive root resorption is if the primary tooth is critical to prevent a malocclusion. For abscessed primary incisors, avoiding disfiguring labial defects to the permanent incisors and preventing cross-bites should be a concern, so extraction of abscessed primary incisors should be strongly considered.

Conclusions

1. Primary tooth zinc oxide-eugenol pulpectomies in 81 teeth had a success rate of 77.7% after followup of 90.8 months. There was no significant difference between molar and incisor success rates.
2. Enamel defects were observed in 18.7% of the succedaneous teeth and were related significantly to the amount of preoperative root resorption. Those pulpectomies on teeth with greater than 1 mm of preoperative root resorption were associated with the highest (44.4%) rate of succedaneous tooth defects.
3. The ZOE pulpectomy procedure was apparently not the source of succedaneous enamel defects. Incidence of enamel defects in teeth replacing pulpectomies was not significantly different from the contralateral untreated controls. Incidence of enamel defects was not related to retention of ZOE filler, length of ZOE fill, or history of trauma or caries.

4. Pulpectomy success was related to the amount of preoperative root resorption. Teeth with excess resorption (> 1 mm) had a success rate of 23.1%, which was significantly lower than teeth without any or minimal preoperative root resorption.
5. Pulpectomy success rate also was related to the length of the ZOE fill. Those filled short of the apex or completely to the apex had a significantly greater success rate than those filled long.
6. The 30 pulpectomized incisors were associated with a 20% incidence of anterior cross-bites or palatal eruption of the succedaneous permanent incisor. The pulpectomized molars required extraction in 21.6% of the cases due to ectopic eruption of the premolar or difficulty in pulpectomy exfoliation.
7. Pulpectomies rarely were lost later than normal. Timing of pulpectomy's loss was not related to retention of ZOE filler. About 36% of the pulpectomies required tooth extraction.

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