Scientific Article

Success of electrofulguration pulpotomies covered by zinc oxide and eugenol or calcium hydroxide: a clinical study

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Abstract

Electrofulguration pulpotomies were completed on 47 primary molars in 38 patients, aged 3 years 1 month to 8 years 1 month. Following electrofulguration, teeth were assigned randomly to one of two groups. In group 1, a zinc oxide and eugenol (ZOE) base was placed over the pulpal stumps and, in group 2, a calcium hydroxide ($Ca(OH)_2$) base was placed. Teeth were evaluated clinically and radiographically after 1, 3, and 6 months by two independent examiners. After 6 months, the clinical success of the ZOE and $Ca(OH)_2$ groups was 77.39 and 81.0%, respectively. Radiographically, after 6 months, the ZOE group had a success rate of 54.6% and the $Ca(OH)_2$ group, 57.3%. There were no statistical differences between the two groups, either clinically or radiographically. (Pediatr Dent 18:385–90 1996)

Pulpotomy is the treatment of choice for cariously exposed pulps in vital primary teeth to maintain the teeth in the oral cavity. With some modifications, the formocresol pulpotomy continues to be used in clinical practice.[1] Formocresol has been shown to have a clinical and radiographic success rate that often exceeds 90%.[2–5] Despite good clinical and radiographic success, histologic findings have been variable, with inflammation and necrosis of the remaining pulpal tissue caused by formocresol demonstrated by various authors.[6, 7] In addition, systemic absorption of formocresol has been demonstrated following multiple pulpotomies in primates[8] and dogs.[9, 10] The acute toxic effects of systemically administered formocresol may include liver and kidney changes.[10]

In an effort to find a more biologically acceptable and effective alternative to formocresol, other agents and techniques have been examined. When calcium hydroxide is utilized in pulpotomies on primary teeth, the success rate is highly variable, with results reported from 22 to 75%.[11–13] Schroder contends that the control of pulpal bleeding is a significant variable in the success of a calcium hydroxide pulpotomy.[11, 13, 14] Leaving a blood clot on the wound surface interferes with healing by producing inflammation and necrosis. Thus, a technique that produces minimal clot formation would be desirable when using calcium hydroxide, perhaps by controlling the bleeding of the pulp stumps prior to placement of medicaments.

The ability of various agents to promote pulpal hemostasis with minimal clot formation has been tested by various authors, with aluminum chloride and ferric sulfate among the pharmacologic agents studied.[12, 15] A nonpharmacologic technique to promote pulpal hemostasis is electrosurgery. Ruemping et al.[16] conducted a 2-month study comparing formocresol and electrosurgical pulpotomy techniques in noncarious primary and permanent teeth of primates. The electrosurgical technique utilized a fully rectified, unfiltered current. A setting was chosen that would prevent sparking or tearing of tissue. In both techniques a zinc oxide eugenol (ZOE) base and amalgam restoration were placed. The teeth were examined clinically, radiographically, and histologically after 2 months, with both groups showing favorable results. Neither group exhibited furcation or periapical involvement, or necrosis of the middle to apical two-thirds of the pulp.

Shaw et al.[17] also evaluated pulpotomies in caries-free primary teeth of primates using a formocresol or electrosurgical technique. A ZOE base was placed followed by an amalgam restoration. After 6 months, 84% of the electrosurgically treated teeth and 80% of the formocresol-treated teeth were judged to be successful, both clinically and histologically.

A study by Shulman et al.[18] also compared electrosurgery and formocresol pulpotomy techniques in the primary teeth of primates. The procedure differed from previous studies, with coronal pulp tissue extirpated

using an electrosurgery current, followed by a coagulation current applied to the pulpal stumps of teeth in the electrosurgery groups. The pulp stumps were then covered with gold foil or a mixture of ZOE with a drop of formocresol. All teeth treated by electrosurgery or electrosurgery and formocresol were considered unsuccessful because periapical or furcation pathology and pathologic root resorption appeared after 65 days.

Two studies using human subjects have been reported. Sheller and Morton[19] performed electrosurgical pulpotomies using 11 caries-free human primary canines. Warm gutta percha then was placed over the stumps and the access sealed with ZOE cement. The teeth were examined clinically, radiographically, and histologically up to 13 weeks postoperatively. Ten of the 11 teeth were judged to be clinically and radiographically successful. Histologically, 7 of the 11 teeth were considered to be successful.

In 1993, Mack and Dean[20] conducted a retrospective evaluation of pulpotomies using an "electrosurgical" technique. A Hyfrecator™ (Birtcher Corp, El Monte, CA, model 733, with electrode model #705-A) was used to apply current to the pulp stumps followed by an IRM base and restoration of the tooth. Radiographic and clinical results revealed a 99.4% (163 of 164) success rate.

In addition to searching for alternatives to formocresol, a further controversy involves the choice of medicament used over the pulp stumps following a pulpotomy. The most commonly used base following a formocresol pulpotomy is ZOE.[21] According to Garcia-Godoy et al.[16] the variability of histologic findings following a pulpotomy procedure using formocresol might also be related to the effects of the ZOE base. Significant pulpal inflammation can be related to the use of ZOE as a sole pulpal medicament.[22] The question of whether the histologic response following electrosurgical pulpotomies was due to the technique or to the ZOE base was raised by Ruemping et al.,[16] Shaw et al.,[17] and Shulman et al.[23] These authors used the ZOE base to compare more directly the results of electrosurgery pulpotomies with the traditional formocresol pulpotomy technique. Ruemping et al.[10] speculated, however, that a coagulation layer produced by electrosurgery might limit the actions of ZOE on the pulp.

As previously discussed, calcium hydroxide has yielded inconsistent results when placed over pulpal stumps in primary teeth. Schroder, in utilizing a "gentle technique", attempted to avoid an extrapulpal blood clot prior to the placement of calcium hydroxide. The author was only somewhat successful, however, with success judged to be between 38 and 59% (eight teeth were lost for unknown reasons) after 2 years. Perhaps by using a pharmacologic hemostatic agent or technique such as electrofulguration in an attempt to limit the size of a blood clot, the success rate following the use of calcium hydroxide might be improved.

The purpose of this study was to assess the clinical and radiographic success of electrofulguration pulpotomies in human primary molars. The success following the placement of a ZOE base was compared with the placement of a calcium hydroxide base over the pulpal stumps following electrosurgery.

Methods and materials

The subjects in this study were selected from the patient population at a hospital-based dental clinic serving children from low-income families in Long Beach, California. Selection was based on the patient having one or more primary molars requiring pulpotomy treatment. The procedures, possible discomforts or risks, as well as possible benefits were explained fully to the human subjects involved. After obtaining written consent, periapical radiographs of the teeth to be treated were exposed using a plastic x-ray film holder. The teeth included in our study were selected according to the following criteria: no tooth mobility, no tenderness to percussion, no swelling or fistulation, and no gross decay or tooth destruction that precluded restoration. Radiographically, the teeth presented a carious pulpal exposure with none of the following present: furcation or periapical pathology or root resorption of more than one-third of the root.

The teeth were assigned randomly to one of two groups:

Group 1: Electrofulguration followed by a ZOE base.

Group 2: Electrofulguration followed by a $Ca(OH)_2$ base.

If a patient presented with more than one tooth requiring a pulpotomy, each tooth was assigned randomly to one of the groups. Each tooth was assigned a numerical code, which was available only to the operator. A total of 38 patients provided 47 teeth for treatment. The patients ranged in age from 3 years 1 month to 8 years 1 month (mean age: 5 years 0.5 months). Seventeen males and 21 females contributed 15 maxillary and 32 mandibular first and second primary molars for study. Forty-three teeth from 35 patients were available for evaluation after 6 months (22 teeth from group 1; 21 teeth from group 2).

After administration of a local anesthetic and isolation of the tooth with a rubber dam, dental caries was excavated and the extent of the carious lesion determined. If a carious pulpal exposure was evident, a high-speed bur (169L, under continuous water irrigation) was used to unroof the pulpal chamber. Coronal pulpal tissue was removed using a sterile slow-speed round bur (#6) or a sterile sharp spoon excavator. Initial hemorrhage control was achieved using dry, sterile cotton pellets. Complete hemostasis then was achieved by using electrofulguration. During the procedure, the active electrode tip was positioned slightly above the pulp tissue and close enough for electrical arcing to occur (about 1 mm above the tissue). A Hyfrecator™ was used in this study. The current was

applied for 1–2 sec over each pulpal stump. If additional fulguration was required, 10 sec elapsed prior to subsequent application of the current. If hemorrhage was not controlled, a pulpectomy was performed and the tooth eliminated from the study. Following control of pulpal hemorrhage by electrofulguration, the teeth were assigned randomly to one of the two experimental groups and received a ZOE or a $Ca(OH)_2$ base covering the treated pulpal stumps. The bases consisted of zinc oxide powder mixed with eugenol liquid or calcium hydroxide powder mixed with sterile water, respectively. The teeth then were restored with stainless steel crowns.

The teeth in the study were evaluated both clinically and radiographically at 1-, 3-, and 6-month intervals. Radiographs were exposed using a Snap-A-Ray™. Clinically, the treatment was considered successful if there was absence of: excessive tooth mobility, subjective symptoms of pain, tenderness to percussion, and fistula. Radiographically, the treatment was considered successful if there was a normal periodontal ligament and absence of furcation or periapical radiolucency, internal or external resorption, and calcific degeneration in the remaining pulp tissue. Clinical and radiographic evaluation was determined by two examiners who had no knowledge of the experimental group of the tooth.

At each recall period, two examiners assessed the clinical success of each tooth. All radiographs were reviewed preoperatively and at each recall period by two examiners following calibration exercises and discussion. Clinical and radiographic success was determined for each group. The overall success of the treatment was then evaluated using both clinical and radiographic findings. If either was judged to be a failure, treatment then was assessed to be a failure. If the examiners disagreed, the poorest outcome was recorded.

The overall success of the two groups was determined and their distribution was tabulated and arranged in a contingency table for both clinical and radiographic evaluations. A chi-square test was performed to determine if significant differences existed between the two groups.

Results

The interobserver reliability determined by the Pearson product moment correlation coefficient was 0.72 ($P < 0.01$).

Clinical results (Table 1)

The teeth in the $Ca(OH)_2$ group had a success rate of 92.3% at 1 month, 86.7% at 3 months, and 81.0% after 6 months. The teeth in the ZOE group had a success rate of 92.3% at 1 month, 86.7% at 3 months, and 77.3% after 6 months. The success of teeth in each group was compared at each of the three time periods. Chi-square analysis revealed no significant differences between each group (Table 1).

Radiographic results (Table 2)

The radiographic success of teeth in the $Ca(OH)_2$ group was 84.6% at 1 month, 66.7% at 3 months and 57.3% after 6 months. In the ZOE group, the success rate

TABLE 1. CLINICAL EVALUATION OF ELECTROFULGURATION PULPOTOMIES

	1 Month			*3 Months*			*6 Months*		
	Success	*Failure*	*Unavailable for Recall*	*Success*	*Failure*	*Unavailable for Recall*	*Success*	*Failure*	*Unavailable for Recall*
$Ca(OH)_2$ Group	12	1	11	13	2	9	17	4	3
ZOE Group	12	1	10	13	2	8	17	5	1
Total	24	2	21	26	4	17	34	9	4
$N = 47$		$P > 0.2$			$P > 0.2$			$P > 0.2$	

TABLE 2. RADIOGRAPHIC EVALUATION OF ELECTROFULGURATION PULPOTOMIES

	1 Month			*3 Months*			*6 Months*		
	Success	*Failure*	*Unavailable for Recall*	*Success*	*Failure*	*Unavailable for Recall*	*Success*	*Failure*	*Unavailable for Recall*
$Ca(OH)_2$ Group	11	2	11	10	5	9	12	9	3
ZOE Group	10	3	10	12	3	8	12	10	1
Total	21	5	21	22	8	17	24	19	4
$N = 47$		$P > 0.2$			$0.1 > P > 0.05$			$P > 0.02$	

was 76.9% at one month, 80% at 3 months and 54.6% after 6 months. Differences between the two groups were found not to be statistically significant, as determined by chi-square analysis (Table 2). The radiographic evaluation included observation of PDL widening, PA radiolucency, internal resorption, external resorption and calcification of the pulp (Table 3). When a tooth was judged to have failed radiographically, it was likely that more that one negative finding was recorded.

TABLE 3. CAUSES OF PULPOTOMY FAILURE

	ZOE Group			*$Ca(OH)_2$ Group*		
	1 Mo.	*3 Mo.*	*6 Mo.*	*1 Mo.*	*3 Mo.*	*6 Mo.*
Clinical failure*	1	2	5	1	2	4
Radiographic failure						
Widened PDL	3	6	7	6	6	7
Periapical radiolucency	2	4	5	2	2	5
Internal resorption	2	2	3	-	1	4
External resorption	2	3	7	1	1	5
Pulpal calcification	-	1	2	2	2	2
Total successful	10	12	12	11	10	12
Total failure	3	3	10	2	5	9

* Presented as parulis, fistula and/or swelling.

Discussion

The results of our study do not support the use of the electrosurgical pulpotomy technique for primary molars having carious pulpal exposures. With clinical success after 6 months measured in the 77–81% range and radiographic success judged to be approximately 55–57%, our findings do not compare favorably with those from previous clinical studies.[19,20]

The term electrosurgery has been used as a broad label and, in fact, includes variations in electrical currents and in equipment. In the current literature, the terms electrosurgery, electrocautery, and electrofulguration are often used interchangeably.

An undamped, fully rectified, high-frequency current in which the electrode is placed in direct contact with the tissues describes a surgical current. The current is said to be biterminal, in which a dispersive grounding plate is required.[23,24] This current may be used with a needle or loop electrode and results in a surgical incision free of any coagulation. If this current is utilized at decreased power, coagulation may occur.[24] A surgical current apparently was used by Ruemping et al.,[16] Shaw et al.,[17] and Sheller and Morton.[19] Shulman et al.[18] used a similar current to amputate the coronal pulp, but followed this amputation with a coagulation current applied to the remaining pulp stumps (Table 4).

According to Oringer[24] a coagulation current results in a superficial zone of coagulation necrosis. The current also is provided biterminally by either electronic equipment or by a spark-gap generator.

The spark-gap generator also can be used to produce fulguration. This is a dehydrating current that can be monoterminal, and the electrode itself does not make contact with tissue. Instead, a spark from the electrode tip is allowed to jump to the tissue. A resultant charring of the tissue or formation of an eschar is found on the surface.[24] According to Sebben[23] the Hyfrecator™, which is a spark-gap generator, is the most popular "electrosurgical" unit in office use by dermatologists. The Hyfrecator was utilized in our study and also by Mack and Dean.[20]

If, according to Oringer, a true surgical current produces minimal coagulation, then the hypothesis put forth by Ruemping et al.[16] is open for debate regarding the significance of any effects caused by a coagulation layer in previous studies using such a current.

Similar currents apparently were used by Shaw et al.[17], Ruemping et al.,[16] and Sheller and Morton,[19] however, somewhat variable histologic results were obtained when these studies were compared. Whether or not a coagulation layer actually was present in any or all of these studies would depend on whether the setting reported of "3–3.5" provided significant power.

Of these studies, both Shaw et al.[17] and Ruemping et al.[16] employed a ZOE base over the treated pulp stumps, while gutta percha was used by Sheller and Morton.[19] The success of the procedures utilized in the former two studies was similar to that of the formocresol technique, while that of the latter study was histologically much less successful. Both Ruemping et al.[16] and Shaw et al.[17] question whether their findings could be attributed to the electrosurgical technique or to the base used. When comparing these two studies with Sheller and Morton's, this variable may be important.

Shulman et al.[18] removed the coronal pulp tissue using surgical current combined with coagulation of the remaining pulp stumps. Not only were two different techniques and currents utilized on the pulp tissue, but the remaining pulp stumps were then covered by either a layer of gold foil or by ZOE base with a drop of formocresol added. The findings of pathologic root resorption and periapical and furcal pathology could be a result of the currents, the "bases", or both. It might be argued that a coagulation layer was most probably generated by the above technique, however, the significance of this layer is unknown when combined with the many other variables.

Both our study and the study by Mack and Dean[20] used a fulguration current applied in a similar manner, but with different results. The techniques used in the two studies were similar and indeed, our study was begun after consultation with the principal author of the previous study to calibrate the equipment and standardize the technique.

TABLE 4. STUDIES UTILIZING ELECTRO "SURGERY"

Authors	*Studied*	*Current*	*Base*	*Length of Study*	*Success Rate*
Ruemping, et al. (1983)[16]	Primates	Surgery	ZOE	1 hr–2 months	Approx. 96% (23/24) histologic success
Shulman, et al. (1987)[18]	Primates	Surgery/ coagulation	Gold foil or ZOE with C^{14} formalin	3–65 days	Approx. 56% (22/39) histologic success
Shaw, et al. (1987)[17]	Primates	Surgery	ZOE	1 hr–6 months	Approx. 84% (25/30) histologic success
Sheller & Morton (1987)[19]	Humans	Surgery	Gutta percha	1 hr–13 weeks	91% (10/11) clinical and radiographic success; 64% (7/11) histologic success
Mack & Dean (1993)[20]	Humans	Fulguration	IRM	1–70 months (retrospective)	99% (163/164) clinical and radiographic success

In our study, the question of whether a particular base placed over the remaining pulpal stumps had a significant effect was addressed. Both Shaw et al.[17] and Ruemping et al.[16] used a ZOE base to compare more closely the electrosurgical technique to the widely used formocresol technique. As previously mentioned, this procedure was found to be successful in both studies. Mack and Dean[20] utilized IRM (a reinforced ZOE dressing) as a base material, also reporting high clinical and radiographic success.

The hypothesis that limiting the size of the blood clot over pulpal stumps would promote a more successful outcome using $Ca(OH)_2$ was not supported by our study. In fact, no significant difference was noted between the success of ZOE or $Ca(OH)_2$ as a base material. Whether the presence of a coagulation layer played any role in this process needs further histologic study. In comparing the results of our study with previous studies utilizing ZOE as a base material, our results are disappointing.

The significance of whether ZOE, $Ca(OH)_2$, or some other material would be a more compatible base deserves further study. Perhaps, as discussed by Sheller and Morton,[19] the electrosurgical technique is more "diagnosis sensitive" and less forgiving than the formocresol method. This would then make proper case selection and use of a particular base material more critical. Further, it became apparent upon review of pretreatment radiographs that signs of pulpal changes could be detected, indicating the potential for more advanced pulpal involvement in several teeth. Thus, current diagnosis would be more critical than with the formocresol technique.

Also worth mentioning is that previous studies by Shaw et al.,[17] Ruemping et al.,[16] and Sheller and Morton[19] all used caries-free teeth for study. Shaw et al.[17] speculated that having a healthy radicular pulp would be necessary for success. Contaminated pulpal tissue might not promote adequate penetration of the current. However, the high success rates reported by Mack and Dean[20] in cariously exposed human teeth, seem to negate that hypothesis.

Our study is considered a pilot, with a small number of teeth and a relatively short recall period. The patients in our study were children from low socioeconomic communities who presented for treatment in a large hospital-based clinic. Ensuring that these patients returned for their prescribed recall examinations was difficult, which resulted in the problem of having fewer patients presenting for the 1-month and 3-month recall exams than for their six-month recall. Future studies should involve a larger patient population and a longer recall time period to evaluate the condition and effects of the pulp following a pulpotomy using the electrofulguration technique.

Until further studies can be accomplished, it would

be premature to recommend this treatment for cariously exposed pulpal tissue in primary teeth.

Conclusions

1. The clinical success rate for electrofulguration pulpotomies was found to be 77–81% after 6 months, while the radiographic success after 6 months was 55–57%.
2. No significant differences in the success of the technique were found when comparing a ZOE base to $CA(OH)_2$ base placed following pulpotomy.

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This study was approved by the Institutional Review Board for the Protection of Human Subjects, University of Southern California (#906014) and by the Research Council, Institutional Review Board, Long Beach Memorial Medical Center (#045-90).

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