

Comparison of electrosurgery and formocresol as pulpotomy techniques in monkey primary teeth

Elliot R. Shulman, DDS, MS F. Thomas McIver, DDS, MS
E. Jefferson Burkes, Jr., DDS, MS

Abstract

The purpose of this study was to compare electrosurgery to formocresol as a pulpotomy technique and to determine the distribution of formocresol in the tooth and periapical tissues in monkeys 3-65 days post-treatment.

Three groups of 20 teeth received pulpotomies using: (1) electrosurgery; (2) ¹⁴C-labeled formocresol in a zinc oxide and eugenol base; or (3) electrosurgery followed by the ¹⁴C-labeled formocresol-zinc oxide and eugenol base. The experimental groups were compared to a control group of 20 teeth which received no treatment. Since pathologic root resorption and periapical/furcal pathology were found in those teeth treated by electrosurgery with or without formocresol, the use of the electrosurgical technique used in this study does not appear to be an effective pulpotomy procedure. The results of formocresol alone were consistent with previous research. Unlike other studies, the ¹⁴C-labeled formocresol was not observed in the periodontal ligament or surrounding bone.

Concern over the use of formocresol in the pulpotomy for primary teeth (Lewis and Chestner 1981; Ranly 1984) has prompted the investigation of several alternatives to this medicament.¹ While some techniques show promise, no alternative medicament has been altogether satisfactory.

Several authors, seeking to avoid the use of medicaments, have suggested electrosurgery for pulpotomies.² The study of this procedure has been limited, but encouraging results have been reported (Law 1957; Ruemping 1983).

A major problem with the conventional formocresol pulpotomy is the potentially harmful effects which could result from formocresol movement out of the dental pulp

into surrounding tissues and the systemic circulation.³ Thus, a technique that either avoids the use of formocresol or confines it to the pulp chamber is desirable. The purpose of this study was to compare histologically the effect on pulp tissue of (1) electrosurgery and (2) electrosurgery and formocresol to the well documented pulpal response to formocresol. Another purpose was to observe the distribution of formocresol in the tooth and periapical tissues.

Methods and Materials

Eighty teeth in 4 *Macaca fascicularis* monkeys with complete noncarious primary dentitions were used in this study. The animals selected were at an age at which physiologic root resorption would not be present. Three arbitrarily assigned treatment groups received pulpotomies with (1) electrosurgery; 2) ¹⁴C-labeled full-strength formocresol incorporated in a zinc oxide and eugenol base (ZOE);⁴ or (3) both electrosurgery and formocresol. The fourth group consisted of untreated teeth used as controls.

Following intramuscular injection of ketamine, general anesthesia was induced in the animals using intravenous sodium pentobarbital. The teeth, isolated with a rubber dam, were cleansed with a solution of iodine and alcohol (1:20). The pulps were exposed through an occlusal preparation made with a #2 round bur rotating at approximately 50,000 r/min. Normal saline was used as both an irrigant and coolant during the preparations. The pulp chamber roof was removed with the round bur after all debris was rinsed from the teeth.

For the first group, pulp tissue was removed using an electrosectioning machine⁵ at a setting of 3.5. Short

¹ Bimstein and Shoshan 1981; Davis et al. 1982; Fuks and Bimstein 1981; Fuks et al. 1984; Fuks et al. 1986; Garcia-Godoy 1983; Morawa et al. 1975; Nevins et al. 1980; Wemes et al. 1982.

² Anderman 1967; Anderman 1976a, 1976b; George 1962; Harris 1976.

⁴ Caulk Temporary Cement — LD Caulk Co; Milford, DE.

⁵ Block et al. 1977; Block et al. 1978a, 1978b; Block et al. 1983; Dilley and Courts 1981; Fulton and Ranly 1979; Mishida et al. 1971; Myers et al. 1978; Myers et al. 1983; Pashley et al. 1980.

strokes were used to remove the pulpal tissue to the level of the canal orifice. Coagulation current at a setting of 4.5 was used at the amputation site. If hemorrhage was not controlled immediately then current was reapplied. Debris was removed from the chamber with a sterile cotton pledget. A piece of .001-inch gold foil was placed carefully on the pulpal floor to act as an inert layer between the pulp stumps and subsequent dressings. A ZOE base was placed over the foil with amalgam alloy condensed over the base.

The second group of teeth had pulps removed with electrosurgery as previously outlined. In addition, a creamy mixture of formocresol, containing one drop of ¹⁴C-labeled formalin,⁵ and ZOE was placed over the canal orifice instead of gold foil. Amalgam then was condensed over this base. In a third group, the coronal pulp was removed with a round bur and hemorrhage was controlled with pressure from moist sterile cotton. A creamy mixture of labeled formocresol-ZOE base as used in the previous group was applied to the canal orifices and amalgam then was condensed over this base.

Following intramuscular injection of ketamine, general anesthesia was induced using intravenous sodium pentobarbital. The four animals were sacrificed by perfusion with 5% formolsaline, as described by Bell (1969), at 3, 14, 41, and 65 days post-treatment. The head was removed and placed in 5% formolsaline for 8 hr. Following fixation, the maxilla and mandible were dissected from the head and periapical radiographs were taken of all teeth. After decalcification in 10% formolcitrate, the jaws were sectioned into blocks, each containing a tooth with its alveolus. All metals were dissected carefully from the teeth. The teeth were embedded in paraffin and 5- μ sections were made of each canal and furcation area of the teeth. Representative slides were dipped in autoradiographic emulsion⁴ and developed as described by Prescott (1964). All slides were stained with H&E.

Results

Of the 80 teeth treated, 3 restorations and bases were lost, eliminating these teeth from the study. One tooth and 1 root of 2 different molars were lost during histologic processing. Radiographic examination confirmed that the primary teeth had not, to an extent detectable by radiographs, begun physiologic resorption.

Radiographic evidence of pathosis or inflammation was observed only after 41 days following treatment; root resorption and furcal radiolucencies were observed after this time. Periapical lesions were difficult to interpret due

to the superimposition of developing tooth buds. All radiographic findings subsequently were confirmed by histologic examination.

The results in this study were based on evaluation of each tooth individually. Therefore, if one canal of a molar exhibited a certain finding, then the tooth was listed as exhibiting that finding.

Control Group

All 16 untreated control teeth presented without inflammation or other disease.

Electrosurgery Group

Figure 1 depicts a pulp three days after electrosurgical treatment. Four histologic zones were found consistently. The most superficial layer contained acellular coagulated protein. The connective tissue stroma was loose and exhibited no cellular detail. Remnants of vascular channels were indistinct. The second zone consisted of cellular and nuclear debris, without any intact cell or nuclei. The connective tissue was more dense than the superficial zone and major blood vessels were evident. A third zone of elongated, spindle-shaped fibroblasts occurred apical to the cell remnant layer, in the stroma. No vital odontoblasts were present. Extravasated red blood cells (RBC) were prominent in this zone along with some scattered inflammatory cells. The fourth zone consisted of a loose connective tissue stroma with plump fibroblastic nuclei and large blood vessels void of RBC. Vital odontoblasts were seen consistently in this zone.

Table 1 summarizes the tissue responses seen in teeth treated with electrosurgery at the various time periods. The pulp tissue at 14 days generally had the same histologic features as the 3-day group with the exception of a significantly smaller normal pulp tissue zone. By 41 days, the pulp tissue in all 4 teeth was degenerating. Periapical granuloma or furcal inflammation frequently was seen by 41 days. An interesting incidental finding at both 3 and 14 days post-treatment was the lack of cellular detail found in the furcal periodontal ligament (PDL) of molars.

Electrosurgery and Formocresol Group

Pulps treated by both electrosurgery and formocresol differed significantly from those treated with only electrosurgery in that with the combined technique a larger portion of the pulp appeared to be affected. Six zones of pulp tissue were seen after 3 days of treatment (Fig 2). A superficial layer of acellular coagulated protein again was present. In the tooth pictured, the current appeared to travel in a vertical direction as can be seen by the extension of the coagulated protein along the root canal. Unlike the previous group, a layer of tissue frequently containing "fixed" odontoblasts along with other

⁵Strobex Mark II Electrosurgical Unit — Whaledent International; New York, NY.

⁶¹⁴C formaldehyde, 10.0 specific activity (250 microcuries diluted with Buckley's formocresol to concentration of 10 microcuries per drop) — DuPont NEN Products; Boston, MA.

⁴Kodak NTB3 — Eastman Kodak Co; Rochester, NY.

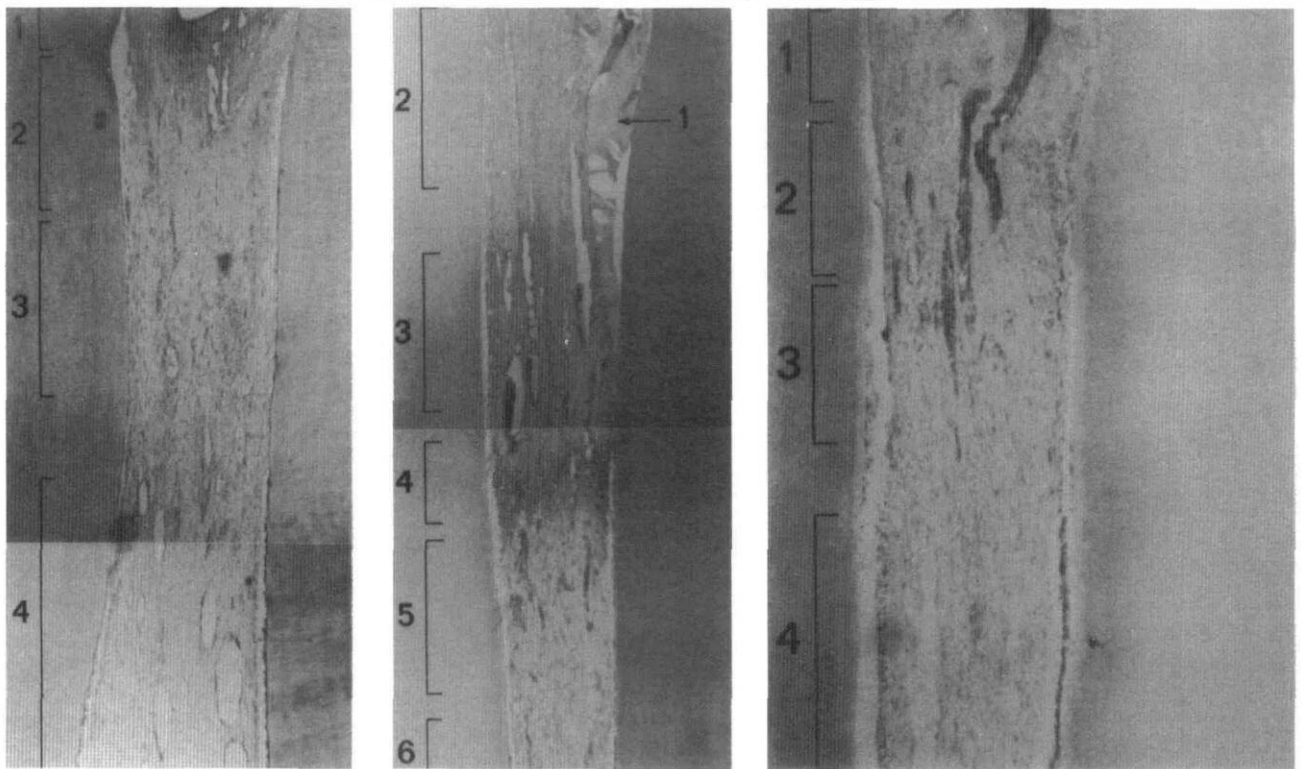


FIG 1 (left) Electrosurgically treated tooth at 3 days showing histologic zones: (1) acellular coagulated protein; (2) cellular remnants; (3) spindle fibroblasts and extravasated blood cells; and (4) normal pulp tissue. Odontoblasts were only present in the normal pulp tissue zone. Also present in the apical region are large blood vessels void of red blood cells. (center) Electrosurgery and formocresol-treated tooth at 3 days showing histologic zones: (1) vertical layer of acellular coagulated protein; (2) fixed cellular zone with remnants of odontoblasts; (3) acellular amorphous connective tissue; (4) degeneration zone; (5) spindle-cell zone; and (6) normal pulp tissue with odontoblasts. (right) Formocresol-treated tooth at 3 days showing affected pulp zones: (1) acellular coagulated protein; (2) fixed cellular layer with blood vessels containing red blood cells; (3) spindle fibroblasts; and (4) normal pulp tissue with odontoblasts. (H&E, 40x)

cell remnants formed the next zone. Apical to the fixed cellular zone, a third zone containing acellular connective tissue with blood vessels was present. A consistent finding in this treatment group was the presence of a degeneration zone. The degenerating cells were often very difficult to distinguish from inflammatory cells. A spindle-cell layer, as with the electrosurgery group, appeared next. Apical to this zone, odontoblasts and normal connective tissue were present.

Table 2 summarizes the tissue responses of teeth treated with both electrosurgery and formocresol. At 3 days, the molars, similar to the electrosurgery only group, showed an acellular furcal periodontal membrane. By 14 days, the pulp tissue presented as strands of connective tissue containing fibroblasts. Further pulpal degeneration with the presence of amorphous tissue was

observed at 65 days. At this same time period 3 of the 5 teeth presented with periapical granulomas. Incomplete reparative dentin bridging was present as early as 14 days and all teeth exhibited this finding by 65 days.

Formocresol Group

Figure 3 illustrates a 3-day specimen with 4 histologic zones of affected pulp tissue. An acellular layer of coagulum was observed at the amputation site. Next a zone containing fixed cellular tissue was seen, similar to that found with the combined electrosurgery and formocresol group. It was also apparent that the RBC were contained within the blood vessels in this treatment group. The usual spindle-cell zone was present, but contained fewer blood vessels. The most apical zone

TABLE 1. Teeth Treated With Electrosurgery Only

Post-Treatment Period (days)	3	14	41	65
Number of teeth with:				
Root resorption	0	0	1	3
Periapical/furcal pathology	0	2	4	3
Reparative dentin formation	0	1	0	4
Number of teeth treated	6	5	4	5

TABLE 2. Teeth Treated With Both Electrosurgery and Formocresol

Post-Treatment Period (days)	3	14	41	65
Number of teeth with:				
Root resorption	0	0	3	4
Periapical/furcal pathology	0	1	1	3
Reparative dentin formation	0	2	2	5
Number of teeth treated	4	5	5	5

contained normal pulp tissue with vital odontoblasts.

The connective tissue beneath the fixed zone was arranged loosely. By 41 days, all pulps exhibited loose strands of connective tissue throughout the canal. The pulpal tissue at 65 days appeared much the same as in the 41-day specimen. Localized coronal abscesses occasionally were seen at 14 and 41 days. Although no pulpal inflammation was present at 65 days, 1 tooth presented with a periapical lesion and root resorption (Table 3).

Comparing the 3 groups in regard to root resorption, it was apparent that the formocresol group had the least root resorption while the electrosurgery and formocresol group was associated most frequently with root resorption.

Autoradiographic Examination

A dense concentration of label was found at the amputation site and surrounding dentin in teeth 3 days post-treatment. The label became less apparent in the apical portions of the pulp and was not visible in the spindle-cell or normal pulp tissue zones. Examination of pulps at 14 and 41 days showed apical migration of the label. By 65 days two findings became apparent: (1) less label was found in the pulp tissue as time progressed; (2) when necrotic pulp tissue was present it was heavily labeled. No significant amounts of label were present in the periodontal membrane, furcal region, bone, or gingiva as determined by quantitative grid microscopy.

Discussion

The results of this study indicate that the electrosurgical technique used does not improve the prognosis of a pulpotomy over a conventional method using form-

ocresol as the pulp dressing. By 41 days the pulps of teeth treated with electrosurgery exhibited signs of irreversible degeneration. In agreement with Law's (1957) study on the pulpotomy using electrosurgery, at 3 days cellular and vascular changes were observed in the coronal portion of the canal leaving the pulp tissue unaffected in the more apical regions.

ocresol as the pulp dressing. By 41 days the pulps of teeth treated with electrosurgery exhibited signs of irreversible degeneration. In agreement with Law's (1957) study on the pulpotomy using electrosurgery, at 3 days cellular and vascular changes were observed in the coronal portion of the canal leaving the pulp tissue unaffected in the more apical regions.

The pulpal histology seen with electrosurgery may have resulted from either the heat produced at the site of contact with electrosurgery or the effect of the electrosurgical current. Since some of the pulp tissue affected was observed some distance from the amputation site, it is likely that the main effect was not by heat cautery, but the

current's traveling down the canal. This finding might be expected with electrosurgery since electrical current follows that path of least resistance which, in the case of a tooth, is likely to be through the root canal. An unusual finding observed with the use of electrosurgery was the acellular PDL. Since this was found in teeth treated either by electrosurgery only or in combination with formocresol, it is likely that the finding is associated with the electrosurgical current. It was of interest that the acellular PDL was found only in the furcations of molars and not in single-rooted teeth. This may be caused by the repeated application of the current for the multiple canals, producing a cumulative effect on the furcal PDL. It is also possible that an area of acellularity in the single-rooted teeth did exist but was not detected on the sections studied. Finally, accessory pulp canals through the furcation floor of the molars may have been responsible for the acellular PDL. Whatever the cause, the acellular PDL seemed not to be associated directly with the prognosis of the tooth, since both anterior and posterior teeth responded similarly.

Although the histologic zones in the 3- and 14-day specimens found in this study appear to concur with those reported by Ruemping et al. (1983), the long-term results differed significantly. Ruemping et al. reported that the electrosurgery technique maintained a vital pulp, whereas this study found a progression to a nonvital pulp. Several differences in methodology may account for the conflicting results. Although both studies used the same type of electrosurgical current, the present study removed the entire pulp tissue with electrosurgery, whereas Ruemping et al. only cauterized the pulp stumps. Since more current was used in this study, it is possible that heat buildup may have occurred despite attempts to limit this factor. It must also be pointed out that this study attempted to avoid any pulpal interaction from other medicaments such as ZOE by using an inert layer of gold foil. Ruemping et al. placed a ZOE material over the treated pulp stumps which may have altered the final results. Combining the results of both primary and permanent teeth in the Ruemping et al. study also may have influenced the results. Due to the many significant differences in the methodologies of the two studies, it is very difficult to compare the results.

Although the initial pulpal response to electrosurgery and formocresol in ZOE was different from that found when electrosurgery was used alone, the results at 65 days post-treatment were similar. Necrotic, often empty, canals were found whether electrosurgery was used alone or in combination with formocresol. It did appear that the addition of formocresol to the treatment regimen reduced the frequency of periapical and furcal inflammation. The addition of formocresol, however, was associated with an increased frequency of root resorption. The resorption may have been caused by necrotic pulp tissue altering the metabolism of the cemento-

TABLE 3. Teeth Treated With Formocresol Only

Post-Treatment Period (days)	3	14	41	65
Number of teeth with:				
Root resorption	0	0	0	1
Periapical/furcal pathology	0	1	0	1
Reparative dentin formation	0	5	3	3
Number of teeth treated	5	6	6	4

clasts and dentinoclasts or the electrical current itself may have played a role in changing the tissue properties. In any case, the results of this study indicated that the addition of formocresol to electrosurgery did not alter the clinical success rate up to 65 days post-treatment.

The appearance of pulps treated with formocresol in a ZOE base was similar to that seen in previous reports by Mejare and Larson (1979) and Beaver et al. (1966) who used a liquid formocresol application. This similarity in findings suggests that formocresol was released from the ZOE base. Although little periapical/furcal pathology or pulpal inflammation was present by 65 days, the pulps were composed of an amorphous tissue rather than tissue with distinct zones as reported by investigators using liquid formocresol application.⁴ An explanation for the differences in pulpal response seen in this study compared to those using liquid formocresol is that the formocresol may not have been released from the ZOE quickly enough to achieve a comparable level of fixation. A second explanation is that due to the small size of monkey pulp chambers, a smaller amount of the formocresol-ZOE base mixture could be placed on the pulp, thereby reducing the amount of formocresol available for pulp fixation.

The finding of reparative dentin in most treated teeth is not felt to be associated with the variables investigated in this study. Treatment of monkey pulps with formocresol previously has been associated with the formation of reparative dentin.⁵ Human studies have not reported the finding of reparative dentin in association with the formocresol pulpotomy. Possibly the pulpal tissue of monkeys is stimulated easily to produce reparative dentin by any type of trauma including formocresol, calcium hydroxide, or other pulp treatments.

The results concerning the distribution of formocresol in this study differ from those reported by Myers et al. (1978), Block et al. (1983), and Fulton and Ranly (1979). Unlike the results reported by Myers et al. and Fulton and Ranly, no evidence of formocresol could be found in either the periodontal ligament or surrounding bone. Labeled formocresol could be detected only in the pulp and nearby dentin. This finding is also in contrast to studies by Block et al. who showed that the root canal can transmit formocresol into systemic circulation. The results of the present study suggest that formocresol did not diffuse from the tooth but rather remained within the pulp.

When comparing the methodology used in this study to that of Myers et al. (1978), a significant difference becomes apparent. They used contact radiography with block sections embedded in methyl methacrylate. No fixative or processing solutions came in contact with the teeth. If the formocresol is bound tightly to the tissues, the

differing methods may not have had an effect on the distribution of the formocresol. However, if it is unbound or loosely bound, it could be translocated in or lost from the tissue during the perfusion fixation procedure or during histologic processing. Fulton and Ranly utilized a different radioisotope, ³H formaldehyde, which may resist translocation during histologic processing.

It is possible that in this study the formocresol was present in the bone and PDL at the time of sacrifice, but the labeled formocresol was not tightly bound and diffused from the tissue during its contact with the various processing solutions. Possibly the label was found in large quantities in the pulp because the pulp is enclosed with only a small apical opening, severely limiting its contact with the solutions that might remove the label.

Conclusions

1. The electrosurgical pulpotomy technique used in this study produced pathologic root resorption and periapical/furcal pathology.
2. The addition of formocresol to the electrosurgically treated tooth produced no better results than when electrosurgery was used alone.
3. Most pulps treated produced reparative dentin, but formocresol appeared to further stimulate its formation.
4. Initially, teeth treated with formocresol in a ZOE base responded with histologic zones similar to those reported for liquid formocresol application.

Since conventional fixation and histologic processing may lead to artifactual redistribution of labeled formocresol and only limited study of the distribution of formocresol using other methods has been done, it is necessary that this topic be investigated further for ¹⁴C labeling. Future areas of investigation should include procedures that require less application of the electrosurgical current and studies of a longer duration. As mentioned previously, the length of exposure to current and heat may be a factor in the degeneration of electrosurgically treated teeth.

This study was supported in part by PHS grants RR05333 and MCJ 00091622-0.

Dr. Shulman is a major, United States Air Force Medical Center, Keesler AFB, Mississippi; Dr. McIver is a professor, pediatric dentistry, and Dr. Burkes is a professor, oral diagnosis, University of North Carolina. Reprint requests should be sent to: Dr. F. Thomas McIver, Dept. of Pediatric Dentistry, School of Dentistry, University of North Carolina, Chapel Hill, NC 27514.

Anderman II: Electronic surgery in modern dental practice. *Bull Ninth Dist Dent Soc (White Plains)* 52:11-13, 1967.

Anderman II: The use of electrosurgery in children's dentistry. *NY State Dent J* 42:223-26, 1976a.

Anderman II: Orthodontic and pedodontic electrosurgery. *Int J Orthod* 14:14-22, 1976b.

⁴Beaver et al. 1966; Berger 1965; Doyle et al. 1962; Emmerson et al. 1959; Massler and Mansukhani 1959; Mejare and Larson 1979.

⁵Boller 1972; Kelley et al. 1973; Spedding et al. 1965.

- Beaver HA, Kopel HM, Sabes WR: The effect of zinc oxide-eugenol cement on a formocresolized pulp. *J Dent Child* 33:381-96, 1966.
- Bell W: Revascularization and bone healing after anterior maxillary osteotomy: A study using adult rhesus monkeys. *J Oral Surg* 27:249-55, 1969.
- Berger JE: Pulp tissue reaction to formocresol and zinc oxide eugenol. *J Dent Child* 32:13-28, 1965.
- Bimstein E, Shoshan S: Enhanced healing of tooth pulp wounds in the dog by enriched collagen solution as a capping agent. *Arch Oral Biol* 26:97-101, 1981.
- Block RM, Lewis RD, Hirsch J, Coffey J, Langeland K: Systemic distribution of [¹⁴C] labeled paraformaldehyde incorporated within formocresol following pulpotomies in dogs. *J Endod* 9:176-89, 1983.
- Block RM, Lewis RD, Sheats JB, Burke SH: Antibody formation to dog pulp tissue altered by 6.5% paraformaldehyde via the root canal. *J Pedod* 2:3-15, 1977.
- Block RM, Sheats JB, Lewis RD, Fawley J: Cell mediated immune response to dog pulp tissue altered by N2 paste within the root canal. *Oral Surg* 45:131-42, 1978a.
- Block RM, Lewis RD, Sheats JB, Burkes SG: Antibody formation to dog pulp tissue altered by formocresol within the root canal. *Oral Surg* 45:282-92, 1978b.
- Boller RJ: Reactions of pulpotomized teeth to zinc oxide and formocresol type drugs. *J Dent Child* 39:298-307, 1972.
- Davis MJ, Myers DR, Switkes MD: Glutaraldehyde: An alternative to formocresol for vital pulp therapy. *J Dent Child* 49:176-80, 1982.
- Dilley GJ, Courts FJ: Immunological response to four pulpal medications. *Pediatr Dent* 3:179-83, 1981.
- Doyle WA, McDonald RE, Mitchell DF: Formocresol versus calcium hydroxide in pulpotomy. *J Dent Child* 29:86-97, 1962.
- Emmerson CC, Miyamoto O, Sweet CA, Bhatia HL: Pulpal changes following formocresol applications of rat molars and human primary teeth. *J South Calif Dent Assoc* 27:309-23, 1959.
- Fuks AB, Bimstein E: Clinical evaluation of diluted formocresol pulpotomies in primary teeth of school children. *Pediatr Dent* 3:321-24, 1981.
- Fuks AB, Michaeli Y, Sofer-Saks B, Shoshan S: Enriched collagen solution as a pulp dressing in pulpotomized teeth in monkeys. *Pediatr Dent* 6:243-47, 1984.
- Fuks AB, Bimstein E, Michaeli Y: Glutaraldehyde as a pulp dressing after pulpotomy in primary teeth of baboon monkeys. *Pediatr Dent* 8: 32-36, 1986.
- Fulton R, Ranly DM: An autoradiographic study of formocresol pulpotomies in rat molars using ³H-formaldehyde. *J Endod* 5:71-78, 1979.
- Garcia-Godoy F: Clinical evaluation of glutaraldehyde pulpotomies in primary teeth. *Acta Odontol Pediatr* 4:41-44, 1983.
- George RK: Use of the hyfurcator in the treatment of pulp exposures. *Dent Dig* 68:114-15, 1962.
- Harris HS: *Electrosurgery in Dental Practice*. Philadelphia; JP Lippincott Co, 1976 pp 3, 4, 78, 79.
- Kelley MA, Bugg JA Jr, Skjonsby HS: Histologic evaluation of formocresol and oxpara pulpotomies in rhesus monkeys. *J Am Dent Assoc* 86:123-27, 1973.
- Law AJ: Pulpotomy by electro-coagulation. *NZ Dent J* 53:68-70, 1957.
- Lewis BB, Chestner SB: Formaldehyde in dentistry: A review of mutagenic and carcinogenic potential. *J Am Dent Assoc* 103:429-34, 1981.
- Massler M, Mansukhani N: Effects of formocresol on the dental pulp. *J Dent Child* 26:277-92, 1959.
- Mejare I, Larson A: Short-term reactions of human dental pulp to formocresol and its components - A clinical experimental study. *Scand J Dent Res* 87:331-45, 1979.
- Morawa AP, Straffon LH, Han SS, Corpron RE: Clinical evaluation of pulpotomies using dilute formocresol. *J Dent Child* 42:360-63, 1975.
- Myers DR, Shoaf HK, Dirksen TR, Pashley DH, Whitford GM, Reynolds KE: Distribution of ¹⁴C formaldehyde after pulpotomy with formocresol. *J Am Dent Assoc* 96:805-13, 1978.
- Myers DR, Pashley DH, Whitford GM, McKinney RV: Tissue changes induced by the absorption of formocresol from pulpotomy sites in dogs. *Pediatr Dent* 5:6-8, 1983.
- Nevins AJ, La Porta RF, Borden BG, Spangberg LS: Pulpotomy and partial pulpectomy procedures in monkey teeth using cross-linked, collagen-calcium phosphate gel. *Oral Surg* 49:360-65, 1980.
- Nishida O, Okada H, Kawagoe K, Tokunaga A, Tanihata H, Aono M, Yokomizo I: Investigation of homologous antibodies to an extract of rabbit dental pulp. *Arch Oral Biol* 16:739-47, 1971.
- Pashley EL, Myers DR, Pashley DH, Whitford GM: Systemic distribution of ¹⁴C formaldehyde from formocresol-treated pulpotomy sites. *J Dent Res* 59:602-7, 1980.
- Prescott DM: *Methods in Cell Physiology*, vol 1. New York; Academic Press, 1964 pp 366-70.
- Ranly DM: Formocresol toxicity. Current knowledge. *Acta Odontol Pediatr* 5:93-98, 1984.
- Ruemping DR, Morton TH, Anderson MW: Electrosurgical pulpotomy in primates - A comparison with formocresol pulpotomy. *Pediatr Dent* 5:14-17, 1983.
- Spedding RH, Mitchell DF, McDonald RE: Formocresol and calcium hydroxide therapy. *J Dent Res* 44:1023-34, 1965.
- Wemes JC, Jansen HWB, Purdell-Lewis D, Boering G: Histologic evaluation of the effect of formocresol and glutaraldehyde on the periapical tissues after endodontic treatment. *Oral Surg* 54:329-32, 1982.