A COMPARISON OF THE FORMOCRESOL
PULPOTOMY TECHNIQUE WITH THE CALCIUM
HYDROXIDE PULPOTOMY TECHNIQUE

By

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INTRODUCTION
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The maintenance of healthy teeth in their normal position in the alveolus has long been considered important by both the laity and dental profession. However, because of the ravages of dental caries, many teeth continue to become affected by carious lesions. When the carious lesion is allowed to progress, the dental pulp may become infected with microorganisms. When the infection is allowed to remain, death of the pulp ensues. The death of the pulp usually results in the extraction of the involved tooth.

It has been found that infected pulps which retain a degree of vitality can be treated and restored to a healthy state, and the teeth maintained in their normal positions in the human masticatory apparatus.

Reports in the literature offer considerable controversy on the effects of various procedures for treating vital teeth which have cariously exposed pulps; there is a particularly great divergence of opinion as to the best means of treating vital primary teeth which have infected pulps as a result of an extension of the caries process. Most of these opinions are based on animal experiments or inadequately controlled clinical observations. Those operations that made the patient comfortable and restored the teeth to a functional state were retained, while those that proved unsuccessful were discontinued. There is, therefore, a definite need for more well-controlled clinical studies which examine the various procedures of treating cariously infected vital primary teeth; there is a particular need to study those procedures which have continued to be used on an empirical basis.
It has been established that the primary dental pulp has the potential to heal and return to a healthy state following injury. The healing potential of the primary dental pulp seems to vary inversely with the degree to which the pulp has been penetrated by the bacterial infection following exposure by the carious lesion. The difficulty of assessing the extent of the infection within the dental pulp has contributed much to the controversy over the best method of treating a bacterially infected primary dental pulp, because the objective of most of the treatment procedures is to remove the portion of the pulp which is infected and to maintain the normal physiologic function of the remaining pulp.

The various procedures which have been advocated for the treatment of cariously exposed dental pulps are pulp capping, pulp curettage, pulpotomy, partial pulpectomy and complete pulpectomy.

Pulp capping is a procedure advocated for teeth which after removal of all of the cariously involved dentine have a "pin point," or very small exposure of the pulp. A dressing is placed over the exposed area of the dental pulp. This dressing, regardless of its content, when placed directly on the exposed tissue of the dental pulp is called the capping material. The tooth is then restored with suitable materials, such as silver amalgam. Pulp capping is advocated on the assumption that an insignificant number of bacteria have invaded the vital dental pulp and the healing potential is favorable.

Another treatment recommended for very small carious exposures of the dental pulp is pulp curettage. In this procedure, a portion of the dental pulp in the immediate area of the carious exposure site is removed in an effort to remove any bacteria present. A pulp capping material is then applied and the tooth is restored by the usual procedures.
Pulpotomy is a procedure which has been widely recommended for the preservation of cariously exposed primary teeth and young permanent teeth. In this technique, the entire coronal portion of the dental pulp is removed by surgical amputation; care is taken not to disturb the portion of the dental pulp which remains in the root portion of the tooth. A capping material is then placed over the remaining pulp stumps, and the treated tooth restored with suitable materials. The popularity of pulpotomy is due to the belief that in a large percentage of instances in which teeth have only moderate areas of pulpal exposure, the area of infection is limited to the coronal portion of the pulp.

Partial pulpectomy is a term which is sometimes used synonymously with pulpotomy. Partial pulpectomy is generally recommended for the treatment of vital primary molars in which bacterial infection appears to have invaded the root portion of the pulp tissue. In this technique all of the coronal pulp tissue is removed, along with all of the pulpal tissue which can be reached with broaches in the root portion of the pulp canals. A pulp capping material is placed in the area formerly occupied by pulp tissue in the pulp canal and the tooth restored with suitable materials.

Complete pulpectomy refers to procedures which attempt the removal of all of the pulpal tissue from the tooth. The empty pulp canals are then obliterated with a filling material and the tooth restored. Complete pulpectomy is usually recommended for completely formed permanent teeth with either vital pulps which are bacterially infected or pulps which are necrotic. In some instances, it is recommended for the treatment of primary teeth which have necrotic or extensively infected pulps.
A large variety of substances have been recommended at various times for use as the pulp capping material. Most of the substances which have been advocated can be divided into two general categories: compounds containing calcium and compounds containing formalin. The most popular representative of each group is calcium hydroxide and formocresol, respectively. The reaction of a healthy human primary dental pulp to either of the capping materials has not been adequately established.

The purpose of this study is to compare the effect of calcium hydroxide with the effect of formocresol on uninfected, healthy, human primary dental pulps, when applied as the capping material after a pulpotomy on sound primary teeth. The study will consist of two approaches to the problem: (1) A histological evaluation, obtained by extracting treated teeth at various intervals up to one year and preparing them for histologic section. (2) A short term clinical evaluation of treated teeth with the use of radiographs and clinical observation.
REVIEW OF LITERATURE
REVIEW OF LITERATURE

Codman,\textsuperscript{1} in 1851, reported success in exciting ossification of the exposed dental pulp. He recommended cleaning the cavity of caries, protecting the exposed pulp from the air with cotton with occasional removal of the cotton to lightly scrape the area in order to stimulate ossification.

Witzel,\textsuperscript{2} in 1881, referred to the work of von Landsdorf, who used dry zinc-oxide and creosote for pulpal capping. Witzel believed that the capping material should be in close relation to the dental pulp.

Buckley,\textsuperscript{3} in 1904, recommended tricresol-formalin for the treatment of putrescent pulps. He believed that:

1. this remedy chemically converted the irritating gases and ptomaines into non-irritating and non-poisonous liquids and solids;
2. the converted liquids and solids were themselves antiseptic and germicidal in character;
3. the medicaments were more effective if applied on cotton, however, a paste could be prepared by mixing the remedy with precipitated calcium phosphate.

When Buckley treated deciduous teeth by pulpotomy, he placed a paste in the pulp chamber and covered it with a quick setting cement. The tooth was then restored with an amalgam filling. He reported that if his procedure were followed, no failures would occur.

Hess\textsuperscript{4} stated that the irregular anatomy of the root canals of teeth made total pulpectomy impossible; thus, various degrees of pulpotomy were being performed when total pulpectomy was attempted. He recommended devitalization of the pulp with a metallic arsenic before pulpotomy and the application of Gysi triopaste over the amputated pulp.
stumps for pulp mummification. Gysi triopaste consisted of:

- tricresol-------------------10cc.
- creolin----------------------20cc.
- glycerin---------------------4cc.
- paraformaldehyde-----------20mg.
- zinc oxide-------------------60mg.

Hess also reported that the pulp must not be more than slightly hyperemic to be considered a candidate for pulpotomy. He examined 62 pulps on a bacteriologic and histologic basis at periods of one to six years following his recommended treatment. All cases presented negative bacteriologic results. Evidence of closure of the root apex by cementum deposition was in process in all cases examined. He further reported that remaining pulp tissue, walled off by the apical closure, remained as a sterile root canal filling. Hess reported that on a clinical basis, 85 percent success could be expected with the technique.

Gurley\(^5\) believed that if the deciduous pulp was exposed by the caries process, it should be devitalized by the use of arsenic fiber or paste previous to performing a pulpotomy. If the exposure was a mechanical one, he recommended capping with a paste consisting of tricalcium phosphate, thymol, phenol and menthol.

Alvord\(^6\) recommended a different type of treatment after the contents of the pulp chamber had been removed. If the tooth was tender to percussion, he placed a pellet of cotton which had been moistened with oil of cloves over the amputated pulp stumps and left an opening in the temporary restoration. If the tooth was not tender, he sealed in a cotton pellet which had been moistened with formocresol over the pulp stumps for 24 to 48 hours. If the tooth was previously tender and was not so at the second appointment, he sealed in formocresol. If the tooth had been previously treated with formocresol, it was isolated, washed and dried, after which the contents of the pulp canal
were removed without going beyond the point of sensation. He then wiped the canals clean with sterile cotton points, gained access to the canals and sealed in a cotton pellet moistened with formocresol for a period of 2 days. At the next appointment, he filled the canals with zinc-oxide and eugenol with silver nitrate and restored the tooth. If any odor or pus was present, however, he repeated the second appointment procedure.

During a discussion of Alvord's paper, McBride said he used a similar technique. McBride said his success with the technique was between 75 and 95 percent.

Orban conducted histological pulp capping studies on an unspecified number of teeth from 14 dogs. He observed that, when paraformaldehyde was placed on the surface of an exposed pulp that necrosis of pulp tissue and inflammation of periapical tissues followed. However, when paraformaldehyde mixed with zinc oxide, in a concentration up to 10 percent, was placed in a cavity having no pulp exposure, the pulp tissue remained vital but showed some evidence of degeneration and much secondary dentin developed.

Foster reported that the most important consideration was a knowledge of when to extract teeth and which ones could be preserved in a healthy condition. He said the majority of dentists at that time treated exposed pulps by devitalizing them with a weak arsenical preparation followed by 1 or 2 sterilizing treatments with formocresol or beechwood creosote. The pulp was then either amputated or extirpated and a paste of zinc oxide and eugenol placed in the canals and chamber. He was of the opinion that pulp capping of deciduous teeth always resulted in failure.
Sweet recommended that exposed deciduous pulps be treated by the pulpotomy technique, followed by the placement of a dressing of formocresol or beechwood creosote for 2 or 3 days. This procedure was then followed by the placement of a second dressing of formocresol or beechwood creosote for another 2 or 3 days. At the third appointment, the chamber was filled with a formocresol-eugenol-zinc-oxide paste and the tooth restored.

Easlick recommended devitalization of all cariously exposed vital deciduous pulps with a paraformaldehyde paste, followed by pulpotomy and capping of the amputated stumps with a zinc-oxide paste. He later reported (1943) clinical success in 70 percent of the cases based on a study of 24 teeth followed for periods ranging from 7 months to 5 years. In the case of very small exposures involving deciduous pulps or the pulps of young permanent teeth, Easlick recommended calcium hydroxide as the capping material of choice.

Helm recommended a devital pulpotomy. For carious exposures of moderate size, involving teeth with or without a history of spontaneous pain, he recommended a pulpotomy and the placement of oxpara paste, consisting of phenol, formaldehyde, creosote, thymol, paraformaldehyde, barium sulfate and iodine.

Natch reported the results of a clinical evaluation of the use of oxpara paste as the capping material in the pulpotomy technique on primary teeth. The study was conducted by the Vancouver study club. Four hundred and sixty-seven vitally exposed pulps were treated. The criteria of success were the lack of clinical symptoms and a normal radiographic appearance of the tooth and surrounding tissue. Thirty teeth in the observation group developed acute symptoms and had to be extracted. The other teeth appeared essentially normal for 2 years,
after which the bone in the bifurcation area demonstrated pathologic change. In many cases the end result was early exfoliation of the primary tooth and early eruption of the succeeding permanent tooth.

Morey\textsuperscript{14} recommended the use of triopaste as the capping material of choice following pulpotomy of primary teeth. He presented radiographs of 8 cases illustrating his results. One case of early exfoliation was attributed to advanced physiologic age. Another case demonstrated pathologic resorption, which he believed was due to infection. He reported that the other 6 teeth remained normal for lengths of time up to 8 years.

Wong\textsuperscript{15} reported the effects of paraformaldehyde preparations on the periapical tissues when used as the capping material following pulpotomy. Six permanent monkey teeth and 28 primary monkey teeth were treated. Both the primary and permanent teeth demonstrated pulpal inflammation, hemorrhage, mucoid and hyaline degeneration, reticular atrophy and fibrosis. Wong reported that when the paraform paste diffused through the resorbed roots of the primary teeth, it came in close proximity to the dental follicle of the developing permanent tooth. The connective tissue of the dental sac lost its fibrous character and became heavily infiltrated with round cells. The ameloblastic layer of the tooth germ was degenerated and some were totally destroyed.

Mansukhani\textsuperscript{16} recently reported a histologic study of 43 deciduous and permanent teeth. An unspecified number of the teeth were exposed by caries and some were non-carious. Pulpotomies were performed using an aseptic technique. The pulp was then cleaned and a dressing of formocresol was applied on a saturated cotton pellet or mixed with
equal parts of eugenol in a paste of zinc-oxide-eugenol-formocresol. The dressing was then sealed into the chamber with either zinc-oxide-eugenol, zinc phosphate cement, or gutta percha for different periods of time; one to 36 minutes, 7 days, 14 days, 30 days, 60 days, and 1 to 3 years, after which, the teeth were extracted and prepared for histologic study. She reported that the surface of the pulp immediately under the formocresol became fibrous and acidophilic within a few minutes after the application of the formocresol. This was interpreted as a "fixation" of the living tissue. After 7 and 14 days of formocresol applications, she observed that the pulp showed three distinctive zones: a broad acidophilic (fixation); a broad pale-staining zone wherein the cells and fibers were greatly diminished (Atrophy); and a broad zone of inflammatory cells concentrated at the junction with the pale-staining zone and diffusing deeply into the underlying pulp tissue of the apex. Mansukhani reported that at 30 days, in the case of human teeth, the three zones previously described had become very broad so that in some cases the inflammatory zone had extended through the apex. At 60 days and at 2 years the formocresol treated pulps were completely fixed and remained only as a strand of eosinophilic fibrous tissue. She also reported no evidence of a calcific bridge at any level and there was no evidence of secondary or reparative dentin formation in any of the specimens examined.

Mansukhani also studied the effects of formocresol when used as the capping material following pulpotomy in 205 rat molars. She reported that the outstanding difference of the pulpal reaction observed in the rat molars was a fibrous encapsulation of the inflammatory zone.
She concluded that the human pulp did not possess the defensive and reparative potentials which characterize the rat molar. She suggested that for maximal effectiveness as a germicide, and minimal action on the pulp tissue that formocresol be applied for 2 to 3 days and for no more than 7 days prior to the placement of the capping material.

Emmerson and his co-workers reported a histological study of 20 cariously and non-cariously exposed primary teeth, as well as 32 rat molars. They sealed formocresol on a pledget of cotton over the amputated stumps for periods of time varying from 5 minutes to 28 days. They observed that applications of formocresol caused a surface fixation of the pulp tissue during a time range of 5 minutes to 3 days. Calcific degeneration occurred in cases in which applications remained longer than 3 days. They also reported that immediately below the amputated area there was a homogeneous yellow staining area, and below that was a normal appearing "fixed" zone of pulp tissue. Below the "fixed" zone there was evidence of degenerated odontoblasts and linear pulpal calcification. Throughout the pulp there was an absence of inflammatory cells and there was no evidence of resorption or metaplastic changes.

Although much of the early work in the field of pulp therapy has been concerned with the use of formalin containing drugs, much of the work of the last 30 years has dealt with pulp capping compounds which contained calcium hydroxide as the principal ingredient.

Hermann is generally acknowledged as being responsible for the introduction of calcium hydroxide as a pulp capping material. He reported histologic material in which he could demonstrate the formation of a dentin-like substance of the exposure site after capping with calyx1, a paste containing Ca(OH)$_2$, KCl, CaCl$_2$, NaHCO$_3$, and NaCl.
Teuscher and Zander\textsuperscript{19} reported the treatment of 120 cases of vital pulp exposure by pulpotomy and then capping the amputated stumps with a thick paste of calcium hydroxide and water. One primary molar and one permanent molar were extracted 14 weeks after treatment and prepared for histologic study. Teuscher and Zander observed that the pulp tissue showed no signs of inflammation. A continuous layer of odontoblasts covered the surface of the pulp at the site of amputation, and had formed secondary dentine which bridged the gap from dentine wall to dentine wall. The outer layer of the dentine bridge was irregular and showed cellular enclosures, while, toward the odontoblasts and the underlying pulp the dentine became more evenly formed with no cellular enclosures and showed regularly arranged dentinal tubuli.

Rosenstein\textsuperscript{20} reported 628 cases of pulp capping in primary teeth. He used copper cement and regular liquid, copper cement and silver nitrate liquid, zinc cement and silver nitrate liquid zinc-oxide and thiol, zinc-oxide and eugenol or other miscellaneous agents as capping materials and believed he had about 90 percent success with each of them. He believed that his success was primarily due to proper diagnosis, which was arrived at by observation of a slight hemorrhage and sensitivity at the exposure site. Later\textsuperscript{21}, he also emphasized the diagnostic importance of a normal color of the tooth structure adjacent to the exposure area. He further recommended that the exposure area be of only moderate or small size before a tooth should be considered a good candidate for pulpotomy.

Peter\textsuperscript{22} reported the treatment of 31 carious deciduous molars by pulpotomy. The amputated pulp stumps were treated with serocalcium, which is a mixture of serum salts with calcium hydroxide. Twenty-five of the treated teeth were extracted and prepared for histologic
examination. Sixty-two percent of the histologically examined teeth were reported as having been successfully treated.

Brown reported 90.2 percent success with the use of calcium hydroxide as the capping material following pulpotomy. His study included 20 permanent teeth and 72 primary teeth. He observed the teeth for periods of time varying from 4 to 47 months after treatment. He reported that aseptic technique and quantity of hemorrhage were not statistically significant in relation to the outcome of the treatment. Brown found that preoperative pain and the size of the pulpal area exposed by the carious process approached statistical significance in relation to the outcome of treatment.

Glass and Zander capped the mechanically exposed pulps of 40 sound bicuspids teeth in children. Twenty of the exposed pulps were capped with zinc-oxide-eugenol and the other 20 were capped with calcium hydroxide and water. The teeth were extracted at specified intervals from 1 day to 12 weeks after capping and prepared for histologic study. All the pulps which were treated with zinc-oxide-eugenol demonstrated varying levels of inflammation and degeneration. The pulps treated with calcium hydroxide were reported as showing at 24 hours after treatment a thin necrotic layer where the medicament was in contact with the pulp. Below the necrotic zone, a layer of calcium proteinate was observed, with normal pulp tissue below the latter. At 2 weeks, they observed the necrotic layer, the layer of calcium-proteinate, then fibrous tissue, similar to primitive bone, with odontoblasts lining up under the fibrous zone and normal tissue below that. At 4 weeks, Glass and Zander observed a complete layer of dentin bridging the exposure site, which had been deposited by the
odontoblasts and normal pulp below the odontoblasts.

Hess\textsuperscript{25} presented a few histologic sections of teeth which had been treated by pulpotomy and capped with calcium hydroxide. He reported 85 to 90 percent success in capping amputated pulps with calcium hydroxide, serocalcium or dentinigene, which is sterile, defatted, powdered dentine. He believed that removal of the wound site from the surface, as in capping, to the canals, as in pulpotomy, enhanced good sealing and success. He believed that failures were due to faulty diagnosis, lack of asepsis, subgingival carious lesions or use of caustic agents or agents damaging to the tissue, such as zinc-oxide-eugenol.

Strange\textsuperscript{26} in a clinical report of pulpotomies treated with calcium hydroxide, considered both primary and permanent teeth. Her criteria of success were the lack of clinical symptoms of failure or perialapical pathology. The teeth were followed for periods of time varying from 7 to 42 months after treatment. Of the 29 primary teeth examined, 26 were judged successful. Of the 16 permanent teeth examined, 12 were judged successful.

Shoemaker\textsuperscript{27} reported the study of 28 teeth which were treated with calcium hydroxide and bone meal following pulpotomy. The study included 19 primary molars and 9 permanent teeth. The teeth were observed for an average of about 18 months after treatment. He reported 32 percent success with the primary teeth and 55 percent success with the permanent teeth.

Kalnins\textsuperscript{28} studied the effects of a paste of calcium hydroxide, sulfathiazole and strontium salts on exposed pulps. The paste was forced into place under pressure. He treated 262 sound and carious permanent and primary teeth. Clinically, 79 percent were asymptomatic.
Of 127 treated permanent teeth, 107 gave a positive vitality test after 2 months to 3 years following treatment. Fifty of the 127 permanent teeth showed a dentin bridge. Of 57 primary teeth which were treated, 6 required root canal therapy or extraction after 1 to 16 months. He extracted 88 treated teeth for histologic examination. He found compression of the connective tissue stroma superficially, suggestive of the formation of a capsule or fibrous metaplasia. Beyond this zone, the tissue appeared undisturbed, and later a dentin bridge developed.

Massler and his co-workers²⁹ performed pulpotomies on the incisors of over 100 rats. They treated the pulp stumps with either calcium hydroxide, zinc-oxide-eugenol, or calcium phosphate. The animals were sacrificed at intervals of 3, 7, 10, 14 and 21 days after treatment, and processed for histological observation of the treated teeth. They reported that the 3 substances produced slight differences in degree of healing, but that the basic pattern of healing was similar. They reported degeneration and necrosis of the pulp tissue zone which was in contact with the capping material. They then observed diffuse calcification of the necrotic layer and occasional bridging of the exposure site by a dentin-like substance.

Nyborg²⁰ studied 44 permanent pulps which were mechanically exposed and capped with calcium hydroxide. The teeth were extracted at intervals of 2 days to 32 months after treatment and processed for histologic study. Thirteen of the teeth presented moderate to marked cellular infiltration and were judged as having a poor healing prognosis. Thirty-one of the teeth were considered as either healed or in the process of healing. Nyborg reported that chances of success when capping pulps with calcium hydroxide under
the conditions of his study were about 70 percent on a histologic basis.

Nyborg also completed various clinical tests on all the capped teeth previous to extraction for histologic study. Upon comparison of the clinical test and the histological condition of the pulps, he concluded that percussion, thermal and electric pulp tests and radiographs were not reliable means of evaluating the condition of the pulp. He said that the most reliable means of determining whether pulpotomy, pulpectomy or root canal therapy should be used were persistent pain and radiographic demonstration of periapical rarefaction or condensation around a thickened periodontal membrane.

Via\textsuperscript{31} reported an evaluation of pulpotomy of primary molars which were treated with calcium hydroxide. He evaluated only mandibular primary molars, which were followed for periods of 9 to 72 months after treatment. His criteria of success were a normal periodontal membrane and lamina dura, a dentin bridge and no internal resorption. He further reported that 14.4 percent of the teeth which evidenced internal resorption had become repaired. Via found no correlation between success of treatment and preoperative clinical diagnosis.

Law\textsuperscript{32} reported a study in which pulpotomy was performed on 251 teeth with carious exposures and calcium hydroxide was applied as a capping material. The cases were selected on the basis of the presence of a normal lamina dura and surrounding bone and no history of spontaneous pain. All pulps were considered to be vital but no effort was made to evaluate the degree of hemorrhage. The cases were followed from 6 months to 5 years after treatment. Criteria of
success were an absence of clinical symptoms such as mobility, pain, tenderness, or pathology of the surrounding tissue. A normal appearance of the lamina dura and bone was considered essential for success, but he did not consider the presence of a dentin bridge to be necessary for a successful evaluation. Upon evaluation of 24 permanent teeth, 20 were considered successful, while only 104, or 46 percent, of the 227 primary teeth responded successfully to the treatment. However, Law reported only 39 percent success in the treated lower primary molars. He believed that the 57 percent success in the upper primary molars was due to caries attacking the lower molars first and the ability to make a better radiographic evaluation of mandibular molars.

Wittich\textsuperscript{33} evaluated pulpotomies performed with calcium hydroxide as the capping material at the University of Minnesota. He reported 67 percent success in primary teeth and 92 percent success in permanent teeth. He believed that in the selection of cases there could be a history of pain of not more than 2 to 3 weeks duration, as long as it was not of the intermittent type or as long as the tooth was not particularly painful upon mastication. Wittich also considered the presence of adequate hemorrhage and no evidence of calcified areas as important signs in diagnosis. He based his evaluation of success upon clinical and radiographic observations.

Nyborg\textsuperscript{34} reported the results of capping 225 cariously exposed permanent pulps with calcium hydroxide. Clinical examinations of the pulps of 81 of the teeth were made during control periods of from 4 hours to 9 years after which they were extracted for histologic study. Of 76 teeth in which no pulpitis had been demonstrable clinically on
capping, the outcome was judged satisfactory in 47 teeth, uncertain in 8, unsatisfactory in 14, and in 7, the results could not be assessed. Of the 5 teeth in which pulpitis had been demonstrable on capping, the histological results were considered to be uncertain in 1 and unsatisfactory in 4. The remaining 144 teeth in the study were observed only on a clinical basis. About 86 percent of the pulps which were considered healthy at the time of capping were successful. Twenty of the teeth in this group demonstrated pulpitis at the time of capping and 11 of the 20 were unsuccessful.

Berman and Massler performed pulpotomies on 122 rat molars. Sixty-one of the teeth were treated with zinc-oxide-eugenol, and 61 with calcium hydroxide. The animals were sacrificed at intervals of 7, 14, 21 and 28 days following treatment, and processed for histologic study of the teeth. At 21 and 28 days after treatment with either zinc-oxide-eugenol or calcium hydroxide, definite reaction zones were observed: the medicament, then a zone of pulpal injury and degeneration, a primary calcific bridge, the permanent bridge of reparative dentin, odontoblastic layer, and normal pulp tissue. Berman and Massler observed that calcium hydroxide had a stronger necrotizing effect on the surface layer of the pulp and that the precalcification started about one week earlier than when zinc-oxide-eugenol was used. They believed that the most important factor in successful treatment of the pulp was adequate sealing of the treated area, and that the action of calcium hydroxide was due to its high alkalinity and coagulating action.

Winter performed pulpotomies on 42 carious primary teeth and used calcium hydroxide as the capping material. The teeth were
extracted for histologic study at intervals of 1 to 30 days after treatment. On a histologic basis, 27 of the teeth presented good prognosis for complete pulpal healing. The other 15 teeth were judged as having unfavorable prognosis.

Winter also correlated various diagnostic procedures with his clinical and microscopic findings. He concluded that there was no apparent relation between preoperative pain and the postoperative condition of the pulp tissue of the teeth employed in the study. He further observed that vitally amputated primary molars manifested no postoperative pain, and that dentin bridge formation was retarded by inflammation of the pulpal tissue. Winter reported that the healing processes observed in primary molar pulps did not differ significantly from the processes described for other types of teeth in previous reports.
METHODS AND MATERIALS
METHODS AND MATERIALS

Sample

The sample consisted of 22 children who were patients at the Indiana University School of Dentistry clinic. There was nothing in the medical history of the children to indicate that they were other than normal, healthy children. They ranged in age from 4 to 11 years and the sex distribution was nearly equally divided with 12 boys and 10 girls.

The children presented 35 primary teeth which could be treated experimentally before their extraction in the course of orthodontic treatment. The children also presented 30 primary teeth which, because of their parents' cooperation, could be treated by experimental pulpotomy and observed clinically. The teeth which were to be treated and later extracted for histologic study were placed in group A (Table I). The teeth which were to be treated and observed clinically were placed in group B (Table II).

The teeth in group A consisted of 33 primary cuspids and 2 primary molars which were either sound or showed evidence of incipient type carious lesions. There were no teeth with carious involvement of the pulp in this group. Whenever possible, corresponding, equally normal teeth in the same patient were treated in order to obtain a comparison of the two types of pulpal therapy, thus reducing the variables to a minimum. By careful selection it was possible to include 15 pairs of teeth in 12 different child patients. There were also 5 unpaired teeth from 5 different patients in group A. The periods of time between experimental treatment and extraction for histologic processing varied from 4 days to 54 weeks.
Group B consisted of 30 primary molars which would normally be retained at least two years after treatment. Twenty-four of the teeth in group B presented incipient type carious lesions while 4 had deep lesions, but not so extensive as to involve the dental pulp. Two teeth in group B presented small carious exposures of the dental pulp. As in group A, corresponding teeth in the same patient were treated when possible. There were 13 pairs of teeth treated in 5 different patients in group B. There were also 4 unpaired teeth treated in 3 additional patients in group B.

As previously mentioned, group B consisted of children whose teeth were to be treated and which were to be followed clinically. The clinical reactions of the dental pulp and the supporting structures to the medicaments were to be observed during the course of this study. Also to be observed at a later date were the exfoliation of time of the experimentally treated teeth and possible effects of the treatment upon the developing permanent dentition; however, because of the time element, these later observations cannot be included in this thesis but will be reported at a later date.

All of the teeth included in this study were considered as normal following the careful and complete preoperative diagnostic procedure. Periapical and bite-wing radiographs were taken of the teeth in order to observe the extent of any carious lesions. The teeth presented no evidence of mobility or sensitivity to percussion and none of the patients had experiences pain of dental origin. The surrounding soft tissue was healthy in all cases.

The usual means of testing pulp vitality with hot, cold or electrical stimuli were omitted, because of previously reported23,30,31
low correlation of such tests with the histologic appearance of the primary pulp and because of the apparent normalcy of the teeth in the study group. However, when the mechanical pulp exposure was made, the pulp was carefully observed for normal appearance and a normal amount of hemorrhage. All of the teeth presented normal amount of hemorrhage. All of the teeth presented normal appearing, vital pulps. Hemorrhage was at a minimum in all cases.

**Operative procedure**

The teeth which were to be treated were anesthetized with Revocaine-HCl, 0.4 percent and Levophed, 1:30,000*. If maxillary teeth were to be treated, labial or buccal infiltration injection of the anesthetic was used. If the teeth were mandibular teeth, an inferior alveolar block injection of anesthetic was administered. The teeth were isolated with a rubber dam and the area swabbed with 70 percent alcohol. The teeth were prepared with a No. 35 inverted cone bur or a No. 558 fissure bur. When the pulp chamber was approached, the field and tooth were again swabbed with 70 percent alcohol. A sterile No. 2 or No. 6 round bur was used to remove the remaining floor of dentin and subsequently the coronal portion of the pulp. The pulpal amputation was made at the entrance to the pulp canal.

Sterile cotton pellets saturated with 4 percent chloramine-T were used to clean the pulp chamber. Remains of the coronal pulp tissue and debris were removed with sterile spoon excavators. Hemorrhage was controlled with cotton pellets moistened with chloramine-T.

All of the teeth in the study were initially treated by the author as previously outlined. Following the amputation of the coronal

* Cook-Walte Laboratories
pulp, half of the remaining pulp stumps were capped with calcium hydroxide; the other half of the pulp stumps were treated with the formocresol technique. In most cases, the two methods were used on corresponding pulps in opposite sides of the same patient's mouth.

**Treatment procedure**

When the calcium hydroxide method was used, a thick mix of calcium hydroxide with one percent methyl-cellulose was applied to the pulp stumps. The paste was gently pressed to place with a sterile cotton pellet. A thick mix of zinc-oxide-eugenol was placed over the calcium hydroxide. In the multiple surface restorations, a layer of thick zinc-phosphate cement was placed over the zinc-oxide-eugenol. The tooth was then restored with silver amalgam alloy. In cases of multiple surface restoration of primary molars, a steel crown was usually placed at a later date, in order to reduce to a minimum the chance of a restoration or tooth fracture.

When the formocresol technique was used, a pellet of cotton moistened with formocresol was placed over the pulp stumps. A dry sterile cotton pellet was then used to gently press the formocresol pellet into place and to blot out any excess formocresol. The cotton pellet with formocresol was then sealed in place with a thick mix of zinc-oxide-eugenol.

The pellet of formocresol was left in place for 4 to 7 days in all but 5 cases. In these 5 cases the pellet was allowed to remain in place for periods of 8 to 42 days in order to observe if leaving the pellet in for a longer time had any effects on the pulp.
At the second appointment, 4 to 7 days following the pulp amputation, the same aseptic procedure was followed as previously outlined. No local anesthetic was necessary, however, at this appointment. The zinc-oxide-eugenol restoration and the cotton pellet with formocresol were removed. Equal parts of formocresol and eugenol were mixed with zinc-oxide to a thick paste. The paste was applied over the pulp stumps in sufficient amount to fill most of the pulp chamber. The capping material was pressed to place with a dry, sterile cotton pellet. In teeth requiring multiple surface restorations, a base of thick zinc-phosphate cement was then applied. The tooth was then restored with a silver alloy. In teeth requiring multiple surface restorations, a chrome steel crown was usually later placed on the treated tooth.

**Histologic procedure**

The teeth to be extracted at various intervals following the experimental procedure were anesthetized as outlined in the operative procedure. The teeth were extracted and care was taken to keep surgical trauma to a minimum. The restorations and most of the base material were quickly removed prior to placement of the tooth in the fixation liquid. In cases of very small apical openings, the apical fifth of the tooth was excised with a diamond disc to facilitate fixation. The teeth were immersed in 10 percent formalin solution and allowed to remain for a minimum of two days for fixation.

The teeth were decalcified in a 5 percent formic acid solution for 2 to 3 weeks. The acid solution was changed daily. They were washed with running water for 24 hours and dehydrated in solutions of alcohol in concentrations varying from 30 percent to 100 percent for
12 to 24 hours at each of the concentrations. The teeth were cut with a scalpel in order to form a flat surface parallel to the dental pulp in order to facilitate later sectioning. Naphtha was used to clear the teeth of alcohol.

The teeth were placed in melted paraffin for 48 hours. Then paraffin blocks containing the teeth were made. The teeth were sectioned in the microtome at a thickness of 7 microns. There was an average of about 35 sections made of each tooth. The cusps were cut in a labio-lingual direction, parallel to the long axis. The two molars were cut in a mesio-distal direction parallel to the long axis. The sections were mounted and stained with hematoxylin-eosin.
RESULTS
RESULTS

In the evaluation of the results, the response of the primary dental pulp to the medicaments, calcium hydroxide and formocresol, was of primary importance. The response to treatment was evaluated on a histologic, radiographic and clinical basis.

The histologic evaluation included examination for evidence of any deviation from what was considered as normal, healthy primary dental pulp tissue. Specific deviations from normal which were considered were:

1. evidence of internal resorption
2. an arbitrary determination of excessive vascularity
3. the presence of inflammatory cells
4. the presence of irregular calcified bodies
5. loss of cellular integrity of the dental pulp, as evidenced by change in appearance or staining characteristics.

The radiographic evaluation included examination for evidence of:

1. a normal periodontal membrane, lamina dura and supporting alveolar bone
2. a normal appearing outline of the pulp canal
3. the position and appearance of the succeeding permanent tooth and surrounding tissue.

The clinical evaluation included a consideration of:

1. history of pain
2. the appearance of the surrounding tissue
3. the adequacy of the restoration which had been placed
4. reaction of the treated tooth to percussion
5. the degree of mobility of the treated tooth.

Marked differences were observed between the pulps which were treated with calcium hydroxide and those which were treated with formocresol (Table 1). These differences will be described.

Histologic Observations of Healthy Primary Dental Pulps Which Were Amputated and Capped with a Dressing of Calcium Hydroxide

Period of treatment: 4-9 days; 4 pulps

All of the pulps in this group presented an essentially normal histologic appearance, however, the necrotic zone at the amputation site included the remnants of the blood clot, the adjacent pulp tissue and, in some instances, dentin chips. Immediately below the necrotic area was a thin layer of darker staining acidophilic tissue, which varied in thickness from 5 to approximately 110 microns. This tissue had the appearance of early osteodentin, and had lacunae in some areas. Below the layer of early osteodentin was normal pulp tissue (Fig. 1). The odontoblasts along the lateral walls of the pulp appeared undisturbed and were considered to have been functioning normally, as evidenced by even deposits of pre-dentin. In one tooth, which was extracted 2 days following the treatment, there appeared to be a "piling up" of odontoblasts on the lateral wall just under the layer of early osteodentin. The prognosis for complete healing of all 4 of these pulps was considered excellent.

Period of treatment: 26 to 49 days; 7 pulps

The pulps observed in this group presented varied postoperative responses. Four of the pulps presented well formed dentin bridges
(Fig. 2) with underlying normal pulp tissue, and were considered as healed. The superficial layer of each of the 4 bridges was composed of a thin zone of osteodentin. Below the osteodentin was a layer of irregular dentin. Under the irregular layer of the bridge was a layer of well formed dentin which was being deposited by a line of well differentiated odontoblasts. Subjacent to the layer of odontoblasts was normal pulp tissue.

The 3 remaining pulps in this group were considered to have reacted unfavorably to the capping material. One of these pulps presented a well formed bridge, but instead of odontoblasts, giant cells were evident immediately under the bridge (Figs. 3A and 3B). The second pulp presented an incomplete bridge with inflammation of the subjacent pulp tissue (Figs. 4A and 4B). The third pulp presented an incomplete bridge, hyperemia and calcific bodies.

**Period of treatment:** 176 to 388 days; 7 pulps

Only one pulp in this group presented a favorable prognosis, the bridge over this pulp presented a small incomplete area, although it was quite thick elsewhere. There was evidence of slight inflammation under the incompletely bridged area, but the remainder of the pulp was normal (Fig. 5).

The other 6 pulps were considered as demonstrating an unfavorable healing response due most frequently to the presence of inflammatory cells and internal resorption (Fig. 6).

**Histologic Observation of Healthy Primary Dental Pulps which were Amputated and Capped with a Dressing of Formocresol**

Healing of the amputation site did not occur in pulps treated with formocresol. The pulps in this group also demonstrated some degenerative changes, which will be described. However, many of these
pulps appeared as though they would not exert any deleterious effects on the surrounding tissues or interfere with the normal functions of the tooth; such pulps were considered to present a favorable appearance (Table 1).

**Period of treatment: 4 to 7 days; 5 pulps**

Because of the short time interval, the second appointment procedure was not performed on these pulps; thus the pellets of formocresol were still in place when these teeth were extracted.

The condition of three of the pulps in this group presented what was arbitrarily considered to be a favorable condition in respect to continued function of the tooth and the probable lack of future harmful effects on the surrounding tissues. The typical appearance of the pulp at the amputation site was the presence of superficial debris from the blood clot, occasional dentin chips and then a layer of compressed, dark staining eosinophilic tissue, which had somewhat of a fibrous appearance (Fig. 7). Below the dark staining zone, the cells of the pulp began to lose their outline form, and the nuclei were also affected in the same manner. The cells appeared as though they had started to degenerate, as evidenced by karyorrhexis and karyolysis. The loss of cellular definition was more apparent as the area of the middle third of the root was approached. The tissue in the middle third of the root also was the palest staining area of the pulp. The odontoblasts along the lateral walls of the pulp were best preserved in the superficial area. As the middle third of the pulp was reached, the odontoblasts were barely evident or completely lost. The blood vessels and blood cells
were quite well preserved throughout the observable pulp tissue. The apical areas of the teeth in this group had been excised to insure adequate fixation, thus no observations of the apical areas of the pulp were made.

Two pulps in this group were considered to be in unfavorable condition. One pulp presented inflammation under the pale staining zone. The other pulp presented inflammation throughout the pulp, especially below the pale staining zone.

**Period of treatment: 35 to 46 days; 6 pulps**

All 6 pulps in this group were assessed as being in satisfactory condition in respect to a probable lack of harmful conditions developing. The appearance of the superficial and middle thirds of the pulp was the same as described in the 3 favorable teeth of the preceding group. Superficially, there were some dentin chips and cellular debris. Below the debris was a dark staining, compressed zone, with well preserved odontoblasts (Figs. 8A and 8B). There appeared to have been some autolysis, with loss of cellular definition, particularly in the middle third of the pulp and towards the apex. The latter areas, which seemed to have degenerated the most, appeared relatively acellular and took a pale stain (Fig. 8C). The blood vessels were still intact in the middle area, but the red blood cell structure was lost, particularly in the upper middle third. The red blood cells appear better preserved towards the apical third. The apices were not excised from all the teeth in this group, thus it was possible to observe a transition from the degenerated faded area to healthy, vital tissue in the apical area of the pulp (Fig. 8D). There was no inflammation evident in any of the pulps of this group.
Period of treatment: 171 to 380 days; 6 pulps

Three of the pulps in this group were considered to be in satisfactory condition. The general appearance of the pulps of this group was approximately the same as the preceding group, except for a greater loss of cellular definition, particularly in the middle third of the pulp (Fig. 9). However, the apical tissue still appeared to be vital. One of the pulps in this group also demonstrated heavy deposits of secondary dentin, and an area of chronic inflammation in the upper middle third area of the pulp. However, since the tissue apically appeared normal, and there was no evidence of internal resorption or other pathology, the condition was considered as satisfactory.

The pulp which had been treated 380 days previous to extraction remained as eosinophilic strands of tissue, with vital tissue remaining in the apical area (Fig. 10).

The other 3 pulps of this group presented unsatisfactory conditions, with inflammatory cells throughout the pulp. One of the pulps presented irregular calcification. Another of these pulps presented internal resorption.

Radiographic Observations of Healthy Primary Dental Pulps which were Amputated and Capped with a Dressing of Calcium Hydroxide (Tables I and II)

Periods of observation following treatment: 4 days to 9 days; 4 pulps

As would be expected for such a short period of observation, all of the pulps and surrounding tissues in this group presented a normal radiographic appearance. Therefore, this group was not included in the radiographic evaluation.
Periods of observation following treatment: 1 month to 19 months; 28 pulps

Eighteen of the pulps in this group presented a normal radiographic appearance. The remaining 10 pulps or their surrounding tissues presented evidence of pathology. Seven of the teeth presented areas of internal resorption (Figs. 11A and 11B). Three teeth presented evidence of loss of bone in the bifurcation area.

Radiographic Observations of Healthy Primary Dental Pulp which were Amputated and Capped with a Dressing of Formocresol (Tables I and II)

Periods of observation following treatment: 4 days to 7 days; 5 pulps

All of the pulps and surrounding tissues in this group presented a normal radiographic appearance, which would be expected for such a short period of observation, thus they were not included in the radiographic evaluation.

Periods of observation following treatment: 1 month to 18 months; 28 pulps

Twenty-six of the pulps and surrounding tissues in this group presented a normal radiographic appearance (Figs. 12A and 12B). One tooth presented evidence of loss of bone in the bifurcation area. The other tooth presented gross internal resorption (Figs. 13A and 13B).

Clinical Observations of the Effects of Amputating Healthy Primary Dental Pulp and Capping them with a Dressing of Calcium Hydroxide or Formocresol

Periods of observation following treatment: 9 months to 19 months; 14 pulps, capping material: calcium hydroxide

Ten of the 14 pulps and surrounding tissues in this group were asymptomatic and presented a normal appearance throughout the observation period. The other 4 teeth were either mobile or sensitive to
percussion. However, there were no complaints of pain, other than when the teeth were intentionally tapped.

Period of observation following treatment: 5 to 18 months. 16 pulps.

capping material: formocresol

None of the teeth in this group presented any evidence of a pathological condition.
# TABLE 1 - GROUP A - HISTOLOGIC GROUP

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<th>Sex</th>
<th>Age of Patient in years</th>
<th>Patient No.</th>
<th>No. of days from treatment to extraction</th>
<th>Capping Material</th>
<th>Radiographic evidence of success</th>
<th>Histologic evidence of success</th>
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1. internal resorption
2. hyperemia
3. calcified bodies
4. inflammatory cells present

U = Maxillary
M = Mandibular
L = Left
R = Right
C = Primary Cuspid
D = First Primary molar
E = Second primary molar
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1. internal resorption
2. loss of bone in bifurcation
3. tooth mobile
4. fistula
5. sensitive to percussion

- U = Maxillary
- M = Mandibular
- L = Left
- R = Right
- C = Primary cuspid
- D = First primary molar
- E = Second primary molar
Figure 1. A photomicrograph of a pulp 5 days after treatment with calcium hydroxide, showing the medicament area (A), the necrotic zone (B), the layer of early osteodontin (C), the fibrous area (D) and normal pulp tissue below (E).
Fig. 1
Figure 2. A photomicrograph of a dentin bridge 28 days after treatment with calcium hydroxide. Note the area of irregular dentin (A), and the layer of evenly deposited dentin (B), with odontoblasts (C) and normal tissue below (D).
Figure 3A. A low power photomicrograph of a completed dentin bridge 30 days after treatment (A) and normal pulp tissue below (B).
Figure 3B. A high power photomicrograph of a completed dentin bridge (A) 30 days after treatment showing the giant cells (B) which were under it.
Figure 4A. A low power photomicrograph of a dentin bridge (A) 38 days after treatment with calcium hydroxide, showing an incomplete area (B).
Figure 4B. A medium power photomicrograph of an incomplete area of a dentin bridge 38 days after treatment. Note the inflammatory cells below the incomplete area.
Figure 5. A low power photomicrograph of a dentin bridge (A) 178 days after treatment with calcium hydroxide. The pulp (B) was essentially normal.
Figure 6. A low power photomicrograph of a primary molar which had been treated with the calcium hydroxide pulpotomy technique 368 days previously. Note the area of internal resorption (A) which had experienced some repair, and the necrotic pulp.
Figure 7. A low power photomicrograph of a pulp which had been treated with formocresol for 4 days. Note the area of the medicament (A), the debris in the blood clot area (B), the eosinophilic, compressed fibrous area (C), and the large pale-staining area throughout the rest of the visible pulp. Note the similarity to the pulp in Figure 8.
Figure 8A. A low power photomicrograph of a pulp which had been treated with formocresol for 41 days.
Figure 88. A medium power photomicrograph of the amputation site after treatment with formocresol for 41 days. Note the dark-staining dentin chips and cellular debris (A), the fibrous, compressed looking acidophilic zone (B), with pale-staining pulp tissue below (C).
Figure 8C. A medium power photomicrograph of the area of the middle third of the root of a pulp which had been treated with formocresol for 41 days. Note the disruption of the odontoblastic layer (A) and the poorly stained nuclei of the pulp cells.
Figure 8D. A medium power photomicrograph of a pulp which had been treated with formocresol for 41 days. Note the transition from the pale-staining zone (A) to normal tissue in the apical area (B).
Figure 9. A low power photomicrograph of a pulp which was treated with the formocresol pulpotomy technique 171 days previously. Note that the most acellular, palest staining area (A) was more superficial than in other cases, and that the acidophilic zone (B) was broader.
Figure 10. A medium power photomicrograph of the apical area of a pulp which had been treated with the formocresol pulpotomy technique 380 days previously. Note that the pale-staining zone (A) extended nearly to the apex, where there was a transition to normal tissue (B).
Figure 11A. A preoperative radiograph of a lower left second primary molar selected for an experimental calcium hydroxide pulpotomy. The carious lesion on the occlusal surface did not extend to the pulpal tissue.

Figure 11B. A radiograph taken one year after treatment with a calcium hydroxide pulpotomy. Note the internal resorption which was beginning in the mesial root canal, and the presence of a dentin bridge over the distal root canal.
Fig. 11A

Fig. 11B
Figure 12A. A preoperative radiograph of a lower right second primary molar selected for an experimental formocresol pulpotomy. The occlusal and distal carious lesion did not extend to the pulpal tissue.

Figure 12B. A radiograph taken one year after treatment with a formocresol pulpotomy. The root canals and surrounding tissue appear normal.
Figure 13A. A preoperative radiograph of a tooth selected for experimental formocresol pulpotomy. The slight mesial and distal caries did not extend to the pulpal tissue.

Figure 13B. A radiograph taken of a tooth 6 months after treatment with a formocresol pulpotomy. Note the gross internal resorption. However, this tooth was clinically asymptomatic.
DISCUSSION
DISCUSSION

The observations of this study are in agreement with previous histologic 19,24,25 and clinical 23,31,32 studies on the effects of calcium hydroxide when used as a capping material on the primary dental pulp. However, the histologic observations of the effects of formocresol on the primary dental pulp observed in this study differ in some respects from previous studies.

Mansukhani16 reported an inflammatory zone immediately under the pale-staining, "fixed" zone which occurred in the middle third area of pulps treated with formocresol, however, normal tissue was observed under the pale-staining zone in the present study. The pale-staining area had the general appearance of an infarct; karyorrhexis and some karyolysis had occurred. Whether this area was actually fixed, necrotic or vital tissue remained to be determined.

Internal resorption was observed in one case in the present study, whereas it had not been observed in previous reports16,17 on the effects of formocresol on the dental pulp.

The calcific degeneration reported by Emmerson and co-workers17 when formocresol was applied to the pulp for periods longer than 3 days was observed in only one case in the present study. The length of time that the pellet of formocresol was applied to the pulp was not a significant factor in the present study. As previously mentioned, the removal of the cotton pellet of formocresol at the second appointment was omitted in some cases. This histologic appearance of the latter pulps corresponded with the appearance of pulps which had been treated with the previously outlined two appointment
formocresol pulpotomy technique. Furthermore, the effects of the formocresol on the pulp were almost as pronounced on pulps which had been treated for a period of 4 days as on pulps which had been treated over a year. Thus, it appeared that the principle effects of formocresol on the primary dental pulp occurred in 4 days or less.

The clinical success of the formocresol pulpotomy technique has been attributed to its germicidal properties. However, the results of this study indicated that its success was due to its action on the pulp tissue. Although healing of the wound site did not occur, the inactivation of the pulp cells and the lack of stimulation of a response by the apical tissue appeared to be desirable effects.

Additional studies should attempt to clarify the period of time that the cotton pellet of formocresol should be left in place over the pulp. The effects of the formocresol-eugenol-zinc-oxide paste should also be established. The effects on the periapical tissue, exfoliation time of the primary tooth, and the succeeding tooth also need investigation.
SUMMARY

The purpose of this study was to compare the effects of the formocresol pulpotomy technique with the effects of the calcium hydroxide pulpotomy technique on mechanically exposed primary dental pulps.

Experimental pulpotomy was performed on the normal pulps of 65 human primary teeth. The formocresol pulpotomy technique was used on 33 of the pulps. The calcium hydroxide pulpotomy technique was employed in treating the other 32 pulps. The study was designed in a manner that allowed a direct comparison of the effects of the two techniques.

Eighteen of the teeth which were treated with the calcium hydroxide pulpotomy technique, and 17 of the teeth which were treated with the formocresol technique were later extracted for histologic study. The time intervals between treatment and extraction varied from 4 days to 368 days; the mean interval was 100 days. Fifty percent of the 18 pulps in the calcium hydroxide group presented a satisfactory histologic appearance. Seventy-one percent of the 17 formocresol treated pulps presented a satisfactory histologic appearance.

On a radiographic basis, the calcium hydroxide pulpotomy technique was 64 percent successful, whereas the formocresol pulpotomy technique was 93 percent successful.

Using clinical criteria, based on observation periods of 9 to 19 months, 71 percent of the pulpotomies which had been capped with calcium hydroxide were successful. The clinical evaluation of the formocresol pulpotomy technique was based on observation periods of 5 to 18 months after treatment; the formocresol group was 100 percent successful.
CONCLUSIONS
CONCLUSIONS

1. Under the conditions of this study the formocresol pulpotomy technique was superior to the calcium hydroxide pulpotomy technique, for at least the first 18 months following the treatment of normal primary dental pulps.

2. Calcium hydroxide was capable of stimulating the formation of a dentin bridge and the complete healing of the stump of the amputated primary dental pulp.

3. Formocresol did not stimulate a healing response by the stump of the amputated primary dental pulp.

4. Calcium hydroxide frequently stimulated inflammation of the remaining pulp tissue and internal resorption.

5. The formocresol pulpotomy technique resulted in a surface layer of well preserved, compressed acidophilic tissue, which appeared to be somewhat fibrous. There was no evidence of calcification or organization. Below the dark staining acidophilic layer, a large pale-staining area of slightly degenerated cells occurred, which extended nearly to the apex. The pale-staining area demonstrated karyorrhexis and karyolysis.
REFERENCES


2. Witzel, A.: The covering of exposed pulps. The Dental Register, 35:1, 1881. (Translated from A. Witzel on Pulp Treatment, by H. Thompson)


BIBLIOGRAPHY
BIBLIOGRAPHY


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Fletke, W. C. et al.: Distribution of \( \text{Ca}^{45} \) applied topically as CaOH after pulpotomy. (ABS.) I.A.D.R., 34:12, 1956.


Witzel, A.: The covering of exposed pulps. The Dental Register, 35:1, 1881.


ABSTRACT
ABSTRACT

A study was undertaken at the Indiana University School of Dentistry pedodontic clinic. The purpose of the study was to compare the effects of the formocresol pulpotomy procedure with the calcium hydroxide pulpotomy procedure on mechanically exposed primary dental pulps. The effects of treatment were evaluated on histologic, radiographic and clinical basis.

Eighteen of the teeth which were treated with the calcium hydroxide pulpotomy technique and 17 of the teeth which were treated with the formocresol technique were later extracted for histologic study. The time interval between treatment and extraction varied from 4 days to 388 days; the mean interval was 100 days. A satisfactory histologic condition of the pulp was observed in 50 percent of the calcium hydroxide group and 71 percent of the formocresol group.

On a radiographic basis, the calcium hydroxide pulpotomy technique was 64 percent successful, whereas the formocresol pulpotomy technique was 93 percent successful.

Using clinical criteria, based on observation periods of 9 to 19 months, 71 percent of the pulpotomies which utilized calcium hydroxide were successful. The clinical evaluation of the formocresol pulpotomy technique was based on observation periods of 5 to 18 months after treatment; the formocresol group was 100 percent successful.

Under the conditions of this study, the formocresol pulpotomy technique was superior to the calcium hydroxide pulpotomy technique, for at least the first 18 months following the treatment of normal primary dental pulps.
VITA
# VITA

Walter A. Doyle

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**Professional Societies:**

- The American Dental Association
- The Indiana State Dental Association
- The Indianapolis District Dental Society
- The American Society of Dentistry for Children
- The Indiana Society of Dentistry for Children