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Ch. 19 Treatment of Deep Caries, Vital Pulp Exposure, and Pulpless Teeth

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LECTURE OUTLINE

- Diagnostic aids in the selection of teeth for vital pulp therapy
- Evaluation of treatment prognosis before pulp therapy
- Treatment of the deep carious lesion
- Vital pulp exposure
- Vital pulp therapy techniques
- Restoration of the pulpally involved tooth
- Reaction of the pulp to various capping materials
- Failures after vital pulp therapy
- Early exfoliation or overretention of primary teeth with pulp treatments
OBJECTIVES

1. The treatment of the dental pulp exposed by the caries process, by accident during cavity preparation, or even as a result of injury and fracture of the tooth.
2. To learn regarding the control of infection and inflammation in the vital pulp.
4. Effective methods of pulp therapy.
DIAGNOSTIC AIDS IN THE SELECTION OF TEETH FOR VITAL PULP THERAPY

1. History of Pain
2. Clinical Signs and Symptoms
3. Radiographic Interpretation
4. Pulp Testing
5. Physical Condition of the Patient
HISTORY OF PAIN

The history of presence or absence of pain may not be as reliable in the differential diagnosis of the condition of the exposed primary pulp as it is in permanent teeth. Degeneration of primary pulp even to the point of abscess formation without the child's recalling pain or discomfort is not uncommon. Nevertheless, the history of a toothache should be the first consideration in the selection of teeth for vital pulp therapy. A toothache coincident with or immediately after a meal may not indicate extensive pulpal inflammation. The pain may be caused by an accumulation of food within a carious lesion, by pressure, or by a chemical irritation to vital pulp protected by only a thin layer of intact dentin. A severe toothache at night usually signals extensive degeneration of the pulp and calls for more than a conservative type of pulp therapy. A spontaneous toothache of more than momentary duration occurring at any time usually means that pulpal disease has progressed too far for treatment with even a pulpotomy.
CLINICAL SIGNS AND SYMPTOMS

A gingival abscess or a draining fistula associated with a tooth with a deep carious lesion is an obvious clinical sign of an irreversibly diseased pulp. Such infections can be resolved only by successful endodontic therapy or extraction of the tooth. Abnormal tooth mobility is another clinical sign that may indicate a severely diseased pulp. When such a tooth is evaluated for mobility, the manipulation may elicit localized pain in the area, but this is not always the case. If pain is absent or minimal during manipulation of the diseased mobile tooth, the pulp is probably in a more advanced and chronic degenerative condition. Pathologic mobility must be distinguished from normal mobility in primary teeth near exfoliation. Sensitivity to percussion or pressure is a clinical symptom suggestive of at least some degree of pulpal disease, but the degenerative stage of the pulp is probably of the acute inflammatory type. Tooth mobility or sensitivity to percussion or pressure may be a clinical signal of other dental problems as well, such as a high restoration or advanced periodontal disease. However, when this clinical information is identified in a child and is associated with a tooth having a deep carious lesion, the problem is most likely to be caused by pulpal disease and possibly by inflammatory involvement of the periodontal ligament.
RADIOGRAPHIC INTERPRETATION

A recent x-ray film must be available to examine for evidence of periradicular or periapical changes, such as thickening of the periodontal ligament or rarefaction of the supporting bone. Radiographic interpretation is more difficult in children than in adults. The permanent teeth may have incompletely formed root ends, giving an impression of periapical radiolucency, and the roots of the primary teeth undergoing even normal physiologic resorption often present a misleading picture or one suggestive of pathologic change.

The proximity of carious lesions to the pulp cannot always be determined accurately in the x-ray film. What often appears to be an intact barrier of secondary dentin protecting the pulp may actually be a perforated mass of irregularly calcified and carious material. The pulp beneath this material may have extensive inflammation. Radiographic evidence of calcified masses within the pulp chamber is diagnostically important. If the irritation is intense and acute and if the carious lesion is developing rapidly, the defense mechanism may not have a chance to lay down the reparative dentin barrier, and the disease process may reach the pulp.
PULP TESTING

The value of the electric pulp test in determining the condition of the pulp of primary teeth is questionable, although it will give an indication of whether the pulp is vital. The test does not provide reliable evidence of the degree of inflammation of the pulp. A complicating factor is the occasional positive response to the test in a tooth with a necrotic pulp if the content of the canals is liquid. The reliability of the pulp test for the young child can also be questioned sometimes because of the child's apprehension associated with the test itself. Thermal tests have reliability problems in the primary dentition, too. The lack of reliability is possibly related to the young child's inability to understand the tests.

Several methods have been developed and advocated as noninvasive techniques for recording the blood flow in human dental pulp. Two of these methods include the use of a laser Doppler flowmeter and transmitted-light photoplethysmography. These methods essentially work by transmitting a laser or light beam through the crown of the tooth; the signal is picked up on the other side of the tooth by an optical fiber and photocell. A distinct advantage of this technique is its noninvasive nature, particularly in comparison to electric pulp testing. Not only is there inaccuracy in the response of the pulp to electric stimuli, but the electric pulp tester may elicit pain. Because the testing may be uncomfortable for young patients, further dental treatment may be affected. A study by Miwa et al suggests that the transmitted-light technique can detect pulpal blood flow in young permanent teeth and is thus applicable to the assessment of pulp vitality.
PHYSICAL CONDITION OF THE PATIENT

Although the local observations are of extreme importance in the selection of cases for vital pulp therapy, the dentist must also consider the physical condition of the patient. In seriously ill children, extraction of the involved tooth after proper premedication with antibiotics, rather than pulp therapy, should be the treatment of choice. Children with conditions that render them susceptible to subacute bacterial endocarditis or those with nephritis, leukemia, solid tumors, idiopathic cyclic neutropenia, or any condition that causes cyclic or chronic depression of granulocyte and polymorphonuclear leukocyte counts should not be subjected to the possibility of an acute infection resulting from failed pulp therapy. Occasionally, pulp therapy for a tooth of a chronically ill child may be justified, but only after careful consideration is given to the prognosis of the child's general condition, the prognosis of the endodontic therapy, and the relative importance of retaining the involved tooth.
EVALUATION OF TREATMENT PROGNOSIS BEFORE PULP THERAPY

The diagnostic process of selecting teeth that are good candidates for vital pulp therapy has at least two dimensions. First, the dentist must decide that the tooth has a good chance of responding favorably to the pulp therapy procedure indicated. Second, the advisability of performing the pulp therapy and restoring the tooth must be weighed against extraction and space management. For example, nothing is gained by successful pulp therapy if the crown of the involved tooth is nonrestorable or the periodontal structures are irreversibly diseased. By the same rationale, a dentist is likely to invest more time and effort to save a pulpally involved second primary molar in a 4-year-old child with unerupted first permanent molars than to save a pulpally involved first primary molar in an 8-year-old child.

Other factors to consider include the following:

1. The level of patient and parent cooperation and motivation in receiving the treatment
2. The level of patient and parent desire and motivation in maintaining oral health and hygiene
3. The caries activity of the patient and the overall prognosis of oral rehabilitation
4. The stage of dental development of the patient
5. The degree of difficulty anticipated in adequately performing the pulp therapy (instrumentation) in the particular case
6. Space management issues resulting from previous extractions, preexisting malocclusion, ankylosis, congenitally missing teeth, and space loss caused by the extensive carious destruction of teeth and subsequent drifting
7. Excessive extrusion of the pulpally involved tooth resulting from the absence of opposing teeth

These examples, in any combination, illustrate the almost infinite number of treatment considerations that could be important in an individual patient with pulpal pathosis.
TREATMENT OF THE DEEP CARIOUS LESION

Many of the lesions appear radiographically to be dangerously close to the pulp or to actually involve the dental pulp. Approximately 75% of the teeth with deep caries have been found from clinical observations to have pulpal exposures. Over 90% of the asymptomatic teeth with deep carious lesions could be successfully treated without pulp exposure using indirect pulp therapy techniques. If a carious exposure discovered at the time of the initial caries excavation could be routinely treated with good results. Unfortunately, the treatment of vital exposures, especially in primary teeth, has not been entirely successful. For this reason, clinicians prefer to avoid pulp exposure during the removal of deep caries whenever possible.
INDIRECT PULP TREATMENT (GROSS CARIES REMOVAL OR INDIRECT PULP THERAPY)

Only the gross caries is removed from the lesion and the cavity is sealed for a time with a biocompatible material. Teeth with deep caries that are free of symptoms of painful pulpitis are candidates for this procedure. The clinical procedure involves removing the gross caries but allowing sufficient caries to remain over the pulp horn to avoid exposure of the pulp. The walls of the cavity are extended to sound tooth structure because the presence of carious enamel and dentin at the margins of the cavity will prevent the establishment of an adequate seal (extremely important) during the period of repair. The remaining thin layer of caries in the base of the cavity is covered with a radiopaque biocompatible base material and sealed with a durable interim restoration. Some interim restorative materials may also serve as the base material. It is often helpful to adapt and cement a preformed stainless steel band to the tooth to support the interim restoration during the observation period. Other operative procedures can be performed at subsequent visits. However, the treated teeth should not be reentered to complete the removal of caries for at least 6 to 8 weeks. During this time the caries process in the deeper layer is arrested. At the conclusion of the minimum 6- to 8-week waiting period, the tooth is reentered. Careful removal of the remaining carious material, now somewhat sclerotic, may reveal a sound base of dentin without an exposure of the pulp. If a sound layer of dentin covers the pulp, the tooth is restored in the conventional manner. Use of a base over the calcium hydroxide liner, in addition to a stainless steel crown, dramatically increases the success rate. If a small pulp exposure is encountered, a different type of treatment, based on the clinical signs and symptoms and local conditions, must be used. The procedure reduces the risk of direct pulp exposure and preserves pulp vitality. One may question the need to reenter the tooth if it has been properly selected and monitored, if a durable restoration is placed initially, and if no adverse signs or symptoms develop. Most clinicians are successfully practicing indirect pulp treatment without reentry after the initial caries excavation. The inexperienced dentist, however, should perform the treatment in two appointments until confidence in proper case selection has been achieved.
VITAL PULP EXPOSURE

The appropriate procedure should be selected only after a careful evaluation of the patient's symptoms, results of diagnostic tests, and conditions at the exposure site. The health of the exposed dental pulp is sometimes difficult to determine, especially in children, and there is often lack of conformity between clinical symptoms and histopathologic condition.

SIZE OF THE EXPOSURE AND PULPAL HEMORRHAGE
The size of the exposure, the appearance of the pulp, and the amount of bleeding are valuable observations in diagnosing the condition of the primary pulp. For this reason the use of a rubber dam to isolate the tooth is extremely important; in addition, with the rubber dam the area can be kept clean and the work can be done more efficiently.

The most favorable condition for vital pulp therapy is the small pinpoint exposure surrounded by sound dentin. However, a true carious exposure, even of pinpoint size, will be accompanied by inflammation of the pulp, the degree of which is usually directly related to the size of the exposure.

DENTAL HEMOGRAM
Guthrie's findings have substantiated the previously mentioned observations. His study was designed to investigate the value of a white blood cell differential count (hemogram) of the dental pulp as a diagnostic aid in determining pathologic or degenerative changes in the pulp. Those teeth in which the inflammatory process was localized to the coronal pulp area were classified as good candidates for a pulpotomy. If the inflammation extended into the pulp canal beyond the area of convenient amputation, the tooth was considered a poor candidate.

The use of the dental hemogram is not a practical diagnostic method in the routine clinical management of vital pulp exposures. However, experimental use of the dental hemogram has confirmed that a history of spontaneous pain and clinical evidence of profuse pulpal hemorrhage tend to correlate well with significant inflammation of pulpal tissue.
DIRECT PULP CAPPING

It is generally agreed that pulp-capping procedures should be limited to small exposures that have been produced accidentally by trauma or during cavity preparation or to true pinpoint carious exposures that are surrounded by sound dentin. Pulp capping should be considered only for teeth in which there is an absence of pain, with the possible exception of discomfort caused by the intake of food. In addition, there should be either no bleeding at the exposure site, as is often the case in a mechanical exposure, or bleeding in an amount that would be considered normal in the absence of a hyperemic or inflamed pulp.

All pulp treatment procedures should be carried out under clean conditions using sterile instruments. Use of the rubber dam will help keep the pulp free of external contamination. All peripheral carious tissue should be excavated before excavation is begun on the portion of the carious dentin most likely to result in pulp exposure. Thus most of the bacterially infected tissue will have been removed before actual pulp exposure occurs. The work of Kakehashi, Stanley, and Fitzgerald" and of Walshe, which is described later in this chapter, supports the desirability of using a surgically clean technique to minimize bacterial contamination of the pulpal tissue.

Calcium hydroxide remains the standard material for pulp capping normal vital pulp tissue. The possibility of its stimulating the repair reaction is good. A hard-setting calcium hydroxide capping material should be used. If the tooth is small (such as a first primary molar), the hardsetting calcium hydroxide may also be used as the base for the restoration. According to Fuks, some recent studies have shown successful results with direct capping of exposed pulps with adhesive bonding agents, whereas others have reported pulp inflammation and unacceptable results using this technique. She therefore suggests that the traditional practice of using calcium hydroxide be maintained.
VITAL PULP THERAPY TECHNIQUES

PULPOTOMY
The removal of the coronal portion of the pulp is an accepted procedure for treating both primary and permanent teeth with carious pulp exposures. The justification for this procedure is that the coronal pulp tissue, which is adjacent to the carious exposure, usually contains microorganisms and shows evidence of inflammation and degenerative change. The abnormal tissue can be removed, and the healing can be allowed to take place at the entrance of the pulp canal in an area of essentially normal pulp. Even the pulpotomy procedure, however, is likely to result in a high percentage of failures unless the teeth are carefully selected. In the pulpotomy procedure the tooth should first be anesthetized and isolated with the rubber dam. A surgically clean technique should be used throughout the procedure. All remaining dental caries should be removed, as well as the overhanging enamel, to provide good access to coronal pulp. Pain during caries removal and instrumentation may be an indication of faulty anesthetic technique. More often, however, it indicates pulpal hyperemia and inflammation, which makes the tooth a poor risk for vital pulpotomy. If the pulp at the exposure site bleeds excessively after complete removal of caries, the tooth is also a poor risk for vital pulpotomy. The entire roof of the pulp chamber should be removed. No overhanging dentin from the roof of the pulp chamber or pulp horns should remain. No attempt is made to control the hemorrhage until the coronal pulp has been amputated. A funnel-shaped access to the entrance of the root canals should be produced. A sharp discoid spoon excavator, large enough to extend across the entrance of the individual root canals, may be used to amputate the coronal pulp at its entrance into the canals. The pulp stumps should be cleanly excised with no tags of tissue extending across the floor of the pulp chamber. The pulp chamber should then be irrigated with a light flow of water from the water syringe and evacuated. Cotton pellets moistened with water should be placed in the pulp chamber and allowed to remain over the pulp stumps until a clot forms. Laboratory and clinical observations indicate that a different technique and capping material are necessary in the treatment of primary teeth than in treatment of permanent teeth. As a result of these observations, two specific pulpotomy techniques have evolved and are in general use today.
VITAL PULP THERAPY TECHNIQUES

Pulpotomy Technique for Permanent Teeth.
The calcium hydroxide pulpotomy technique is recommended in the treatment of permanent teeth with carious pulp exposures when there is a pathologic change in the pulp at the exposure site. This procedure is particularly indicated for permanent teeth with immature root development but with healthy pulp tissue in the root canals. It is also indicated for a permanent tooth with a pulp exposure resulting from crown fracture when the trauma has also produced a root fracture of the same tooth. The procedure is completed during a single appointment. Only teeth free of symptoms of painful pulpitis are considered for treatment. The procedure involves the amputation of the coronal portion of the pulp as described, the control of hemorrhage, and the placement of a calcium hydroxide capping material over the pulp tissue remaining in the canals. A protective layer of hard-setting cement is placed over the calcium hydroxide to provide an adequate seal. The tooth is subsequently prepared for full-coverage restoration. However, if the tissue in the pulp canals appears hyperemic after the amputation of the coronal tissue, a pulpotomy should no longer be considered. Endodontic treatment is indicated if the tooth is to be saved. After 1 year, a tooth that has been treated successfully with a pulpotomy should have a normal periodontal ligament and lamina dura, radiographic evidence of a calcified bridge if calcium hydroxide was used as the capping material, and no radiographic evidence of internal resorption or pathologic resorption. The treatment of permanent teeth by the calcium hydroxide method has resulted in a higher rate of success when the teeth are selected carefully based on existing knowledge of diagnostic techniques.
Pulpotomy Technique for Primary Teeth.
The same diagnostic criteria recommended for the selection of permanent teeth for the pulpotomy procedure should be used in the selection of primary teeth for the pulpotomy procedure. The treatment is also completed during a single appointment. A surgically clean technique should be used. The coronal portion of the pulp should be amputated, and the hemorrhage should be controlled. If there is evidence of hyperemia after the removal of the coronal pulp, which indicates that inflammation is present in the tissue beyond the coronal portion of the pulp, the technique should be abandoned in favor of the partial pulpectomy or the removal of the tooth. If the hemorrhage is controlled readily and the pulp stumps appear normal, it may be assumed that the pulp tissue in the canals is normal, and it is possible to proceed with the pulpotomy. The pulp chamber is dried with sterile cotton pellets. Next, a pellet of cotton moistened with a 1:5 concentration of Buckley's formocresol and blotted on sterile gauze to remove the excess is placed in contact with the pulp stumps and is allowed to remain for 5 minutes. Because formocresol is caustic, care must be taken to avoid contact with the gingival tissues. The pellets are then removed, and the pulp chamber is dried with new pellets. A thick paste of hard-setting zinc oxide-eugenol is prepared and placed over the pulp stumps. The tooth is then restored with a stainless steel crown.
PARTIAL PULPECTOMY

A partial pulpectomy may be performed on primary teeth when coronal pulp tissue and the tissue entering the pulp canals are vital but show clinical evidence of hyperemia. The tooth may or may not have a history of painful pulpitis, but the contents of the root canals should not show evidence of necrosis (suppuration). In addition, there should be no radiographic evidence of a thickened periodontal ligament or of radicular disease. If any of these conditions is present, a complete pulpectomy (described later) or an extraction should be performed. The partial pulpectomy technique, which may be completed in one appointment, involves the removal of the coronal pulp. The pulp filaments from the root canals are removed with a fine barbed broach; considerable hemorrhage will occur at this point. A Hedstrom file will be helpful in the removal of remnants of the pulp tissue. The file removes tissue only as it is withdrawn and penetrates readily with a minimum of resistance. Care should be taken to avoid penetrating the apex of the tooth. Many dentists prefer to use root canal instruments placed in a special handpiece for root canal debridement. Cautious manipulation is important, however, to prevent breaking the file or overinstrumenting the canal and apical tissues. After the pulp tissue has been removed from the canals, a syringe is used to irrigate them with 3% hydrogen peroxide followed by sodium hypochlorite. The canals should then be dried with sterile paper points. When hemorrhaging is controlled and the canals remain dry, a thin mix of unreinforced zinc oxide-eugenol paste may be prepared (without setting accelerators), and paper points covered with the material are used to coat the root canal walls. Small Kerr files may be used to file the paste into the walls. The excess thin paste may be removed with paper points and Hedstrom files. A thick mix of the treatment paste should then be prepared, rolled into a point, and carried into the canal. Root canal pluggers may be used to condense the filling material into the canals. An x-ray film may be necessary to allow evaluation of the success in filling the canals. The tooth should be restored with full coverage. Although zinc oxide—eugenol paste is viewed as the traditional root canal filling material for primary teeth (KRI paste: zinc oxide and iodoform, resorbs in synchrony with primary roots and is less irritating to surrounding tissues if a root is inadvertantly overfilled. (Vitapex: hydroxide and iodoform).
COMPLETE PULPECTOMY

The morphology of the root canals in primary teeth makes endodontic treatment difficult and often impractical. Mature first primary molar canals are often so small that they are inaccessible even to the smallest barbed broach. If the canal cannot be properly cleansed of necrotic material, sterilized, and adequately filled, endodontic therapy is more likely to fail. The subsequent deposition of secondary dentin throughout the life of the teeth caused a change in the morphologic pattern of the root canal, producing variations and eventual alterations in the number and size of the canals. The variations included lateral branching, connecting fibrils, apical ramifications, and partial fusion of the canals.

Endodontic procedures for the treatment of primary teeth with necrotic pulps are indicated if the canals are accessible and if there is evidence of essentially normal supporting bone. If the supporting bone is also compromised, the likelihood of successful endodontic therapy is lower. If the second primary molar is lost before the eruption of the first permanent molar, the dentist is confronted with the difficult problem of preventing the first permanent molar from drifting mesially during its eruption. Special effort should be made to treat and retain the second primary molar even if it has a necrotic pulp. Similarly, longer than normal retention of a second primary molar may be desired when the succedaneous second premolar is congenitally missing. The rubber dam should be applied, and the roof of the pulp chamber should be removed to gain access to the root canals as described previously in the pulpotomy technique. The contents of the pulp chamber and all debris from the occlusal third of the canals should be removed, with care taken to avoid forcing any of the infected contents through the apical foramen. A pellet moistened with camphorated monochlorophenol (CMCP) or a 1:5 concentration of Buckley’s formocresol, with excess moisture blotted, should be placed in the pulp chamber. The chamber may be sealed with zinc oxide–eugenol. At the second appointment, several days later, the tooth should be isolated with a rubber dam and the treatment pellet removed. If the tooth has remained asymptomatic during the interval, the remaining contents of the canals should be removed using the technique described for the partial pulpectomy. The apex of each root should be penetrated slightly with the smallest file. (The dentist should experiment with dissociated primary molars to develop a feel for the instrument as it just penetrates the apex.) A treatment pellet should again be placed in the pulp chamber and the seal completed with zinc oxide- eugenol. After another few days the treatment pellet should be removed. If the tooth has remained asymptomatic, the canals may be prepared and filled as described for the partial pulpectomy. However, if the tooth has been painful and there is evidence of moisture in the canals when the treatment pellet is removed, the canals should again be mechanically cleansed and the treatment repeated. Currently, pulpectomies in primary teeth are commonly completed in a single appointment.
RESTORATION OF THE PULPALLY INVOLVED TOOTH

Primary and permanent molars that have been treated by the pulpotomy or pulpectomy technique have a weak, unsupported crown that is liable to fracture. Often a failure of the buccal or lingual plate occurs below the gingival attachment or even below the crest of the alveolar bone. This type of fracture makes subsequent restoration of the tooth impractical. Also, a delay in restoring the tooth with a material that will adequately seal the tooth and prevent an ingress of oral fluids is one cause for failure of pulp therapy. Application of a layer of hard-setting cement over the capping material followed by a substantial restoration will adequately protect the pulp against contaminating oral fluids during the healing process. An amalgam restoration, a composite resin restoration, or a glass ionomer restoration may serve as the immediate restoration and often the final restoration for teeth with pulp caps and well-supported crowns. As soon as it is practical, however, other pulpally treated posterior teeth should be prepared for stainless steel or cast crowns. Pulp treatment of a primary molar is often followed by placement of a stainless steel crown restoration during the same appointment.
REACTION OF THE PULP TO VARIOUS CAPPING MATERIALS

ZINC OXIDE-EUGENOL
Many dentists have apparently had good clinical results with the use of zinc oxide-eugenol, but it is no longer recommended as a direct pulp-capping material.

CALCIUM HYDROXIDE
Herman first introduced calcium hydroxide as a biologic dressing. Because of its alkalinity (pH of 12), it is so caustic that when it is placed in contact with vital pulp tissue the reaction produces a superficial necrosis of the pulp. The irritant qualities seem to be related to its ability to stimulate development of a calcified barrier. The superficial necrotic area in the pulp that develops beneath the calcium hydroxide is demarcated from the healthy pulp tissue below by a new, deeply staining zone comprising basophilic elements of the calcium hydroxide dressing. The original proteinate zone is still present. However, against this zone is a new area of coarse fibrous tissue likened to a primitive type of bone. On the periphery of the new fibrous tissue, cells resembling odontoblasts appear to be lining up. One month after the capping procedure, a calcified bridge is evident radiographically. This bridge continues to increase in thickness during the next 12 months. The pulp tissue beneath the calcified bridge remains vital and is essentially free of inflammatory cells.
REACTION OF THE PULP TO VARIOUS CAPPING MATERIALS PREPARATIONS CONTAINING FORMALIN

The clinical success experienced in the treatment of primary pulps with these materials is related to the drug's germicidal action and fixation qualities rather than to its ability to promote healing. Formocresol pulpotomy technique yielded outcomes superior to those of the calcium hydroxide technique for at least the first 18 months after treatment. The results of the combined methods of evaluation indicated that the calcium hydroxide pulpotomy technique for primary teeth was successful in 61% of cases. The formocresol pulpotomy resulted in success in 95% of cases at the end of 1 year. Formocresol did not stimulate the healing response of the remaining pulp tissue but rather tended to fix essentially all the remaining tissue.

GLUTARALDEHYDE

It is an excellent bactericidal agent and seems to offer some advantages compared with formocresol in the following ways: 1. Formaldehyde reactions are reversible, but glutaraldehyde reactions are not. 2. Formaldehyde is a small molecule that penetrates the apical foramen, whereas glutaraldehyde is a larger molecule that does not. 3. Formaldehyde requires a long reaction time and an excess of solution to fix tissue, whereas glutaraldehyde fixes tissue instantly and an excess of solution is unnecessary.
FERRIC SULFATE
Ferric sulfate agglutinates blood proteins and controls hemorrhage in the process without clot formation. It appears that ferric sulfate could be a better choice for treating primary teeth needing pulpotomy (equal results to dilute formocresol but with less toxicity). Main advantage of the ferric sulfate pulpotomy over a pulpectomy when working with children is the considerably faster speed with which a pulpotomy can be performed.

OTHER EXPERIMENTAL CAPPING MATERIALS (MINERAL TRIOXIDE AGGREGATE, BONE MORPHOGENETIC PROTEIN, AND OTHERS)