International Endodontic Journal (1981) 14, 166–172

Management of the open (immature) apex. 1. Vital teeth

J. L. GUTMANN, DDS & J. F. HEATON, DMD *Department of Endodontics, Baltimore College of Dental Surgery, University of Maryland at Baltimore, Baltimore, Maryland, USA*

Introduction

As dental practitioners, we are frequently faced with managing the young, immature pulp which has been compromised by trauma or caries. Under no circumstances should root canal therapy be the immediate treatment of choice where a vital pulp is present and the apex of the tooth in question has not developed sufficiently to permit the uncomplicated mechanics of endodontic instrumentation and obturation. Our primary objective in the management of these cases is to create an environment conducive to continued root formation and closure, i.e. apexogenesis.

Treatments of choice would be indirect pulp capping (Law & Lewis 1961, Held-Wydler 1964, Starkey 1968, Canby & Burnett 1963), direct pulp capping (Winter 1977, Corpron & Dowson 1970), partial pulpotomy (Cvek 1978), also referred to as *pulpal curettage* by Berk *et al.* (1975), or total coronal pulpotomy (Krakow *et al.* 1977, Naidorf 1970). Although these procedures are performed to promote pulpal healing and to stimulate new dentine formation, their primary purpose in this instance is to maintain the vitality and the integrity of the radicular pulp tissue so root lengthening and apical closure can ensue.

Indirect pulp capping

In cases of deep caries where further excavation would most probably result in a pulp exposure and an immature apex is present, indirect pulp capping is the recommended procedure. Based on clinical findings of an asymptomatic tooth and no abnormal radiographic changes, the nature of the carious lesion may be such that the deeper layers are relatively free of micro-organisms (Dorfman *et al.* 1943, Parikh *et al.* 1963, Massler 1967, Shovelton 1968, Langeland & Langeland 1968) and have been demineralized by bacterial products. Ideally, all teeth considered for indirect therapy should demonstrate radiographically attempts at reparative dentine between the deep caries and the dental pulp (Reed 1977). Therefore, the removal of the highly contaminated layer of dentine and the placement of an appropriate dressing will not only allow the possible remineralization of the affected dentine (Massler 1967), but also, due to the large apical blood supply and pulpal reparative capabilities, will allow an increased layer of reparative dentine to form. Although DiMaggio & Hawes (1963) have reported a high histological success rate for indirect therapy, clinically, continued root formation to completion visible on the radiograph is a strong indication of successful treatment.

The clinical technique for performing the indirect pulp capping procedure is as follows. Under proper isolation, i.e. rubber dam, prepare an outline form and remove the clinically soft carious dentine (infected dentine; Massler 1967). When approximating the pulp, removal of the final portion of the soft dentine with hand instruments, i.e. sharp spoon curettes, allows for a better tactile appraisal of the texture of the involved dentine. However, stop prior to removal of the last layer of carious dentine which might possibly cause an exposure, and place a layer of calcium hydroxide or zinc oxide-eugenol over the dentine and remaining

Correspondence: James L. Gutmann, DDS, Department of Endodontics, Baltimore College of Dental Surgery, Dental School, University of Maryland at Baltimore, Baltimore, Maryland 21201, USA.

0143–2885/81/0900–0166 $02.00

carious material (King *et al.* 1965). Subsequently, the tooth should receive a temporary restoration which provides a good, long-lasting seal against contamination from oral fluids, or a final restoration, i.e. amalgam may be placed. Ideally, re-excavation should occur in 6–8 weeks to determine the status of the carious material which is left, although this course of treatment may depend greatly on patient availability.

Where trauma has resulted in a class II fracture and there is an immature apex, treatment should be initiated to protect the exposed dentine. The use of cavity varnish or the placement of a base of calcium hydroxide followed by a good sealing temporary restoration is indicated (Case No. 1, Figs. 1–4).

Direct pulp capping

There is a general agreement that direct pulp capping may be the treatment of choice following traumatic exposure in teeth with immature apices where the coronal tooth loss is minimal, the exposure is small, and the time interval since injury is short, e.g. 1–2 hours (Massler *et al.* 1957, Kopel 1976, Winter 1977). However, in the case of a carious exposure, Seltzer & Bender (1975) discourage direct pulp capping since microorganisms and inflammation are invariably associated with the pulp beneath the exposure. The presence of bacterial contamination superimposed on an already chronically inflamed pulp will most likely lead to degenerative pulpal changes which may prevent the continued development of the root. Therefore, where a carious exposure exists, a more extensive procedure such as a partial pulpectomy is indicated (Dannenberg 1974).

In the case of a traumatic exposure, the tooth should be properly isolated with a rubber dam and the exposed area gently cleaned with hydrogen peroxide, sterile saline, or a dry sterile cotton pellet. The exposure is covered with calcium hydroxide (Frankl 1972, Seltzer & Bender 1975) and sealed with a quick-setting zinc oxide–eugenol cement followed by a permanent restoration to prevent leakage of oral fluids which will cause failure of the procedure.

Direct pulp capping should not be considered for the tooth with immature apical development if spontaneous pain exists, there is radiographic evidence of pulpal or periapical pathosis, excessive haemorrhage at the exposure site, or exposure exhibiting purulent or serous exudates.

As with indirect pulp capping, patient observation is essential to determine whether or not normal apical lengthening and closure ensues or additional intervention is necessary due to patient symptomatology or adverse radiographic or clinical findings.

Partial pulpectomy (partial pulpotomy)

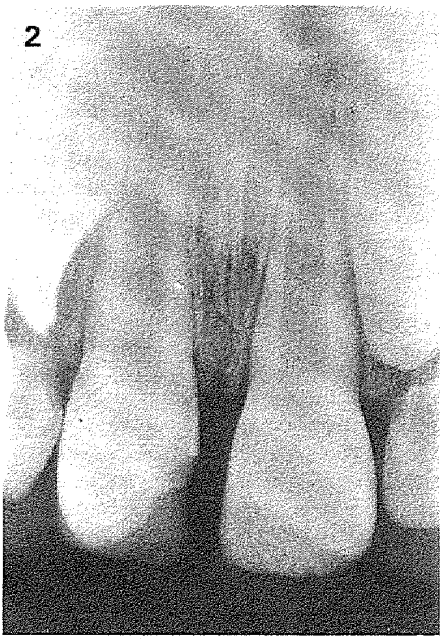
A partial pulpectomy has been advocated in larger pulp exposure resulting from immediate trauma or even when treatment is initiated long after the initial traumatic exposure (7–10 days or longer) (Cvek 1978). The healthy pulp's response to fracture and contamination appears to be a hyperplastic pulpitis restricted to the superficial layers of the coronal pulp. This response may serve as a barrier to the further ingress of microorganisms and their toxic products.

Removal of the superficial portion of the coronal pulp and surrounding dentine, proportional to the area of the exposed pulp, is accomplished with a cylindrical or cone-shaped sterile bur in a high-speed handpiece, accompanied by a generous amount of flushing with sterile saline (Cvek 1978). Following the control of haemorrhage with saline, the pulp wound is covered with calcium hydroxide and sealed with a zinc oxide – eugenol cement. Re-excavation is recommended in 4–6 months along with radiographic evaluation to determine the extent of the reparative dentine response and continued root development.

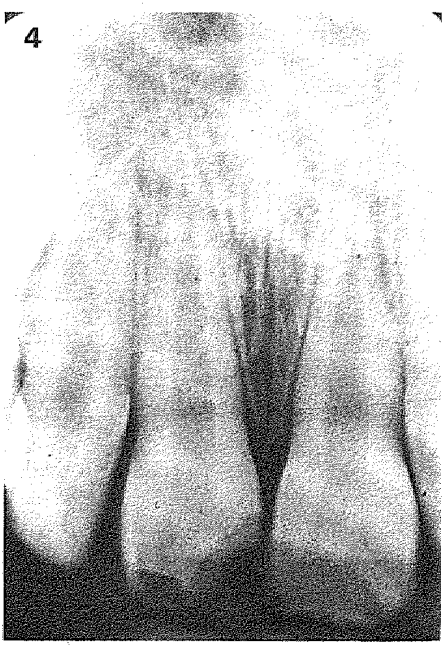
Total coronal pulpectomy (pulpotomy)

A total coronal pulpectomy is indicated when the coronal pulp has been severely


1


2


3


4

compromised, yet the radicular pulp is still sound (Shiere *et al.* 1961, Law 1961, Hartsook 1966, Corpron & Dowson 1970). Clinically, this is determined by 1 a normal radiographic appearance; 2 no percussion sensitivity; 3 slight, if any, response to thermal stimulation; 4 little, if any, purulent exudate; 5 absence of odour; and 6 normal haemorrhage is observed when amputation occurs and can be easily controlled (Britton 1976).

Under conditions of profound anaesthesia and good isolation, all caries is removed and toilet of the cavity is accomplished prior to removal of the pulp chamber roof. Careful removal of the dentine roof is accomplished by circumscribing the hard tissue to be removed with a round bur, followed by lifting the roof off the tissue with a spoon excavator. This procedure should reveal the odontoblastic membrane. If this membrane is no longer firm and resilient, the radicular pulp may have undergone degenerative changes (Krakow *et al.* 1977), and treatment as a necrotic pulp with an open apex may be indicated.

The healthy odontoblastic membrane appears as a shiny, glossy tissue, purplish-grey in colour. This is amputated with a sterile, sharp, spoon excavator in order to prevent the pushing of dentinal debris into the pulp stump wound (Kalnins & Frisbie 1960, Berk & Krakow 1972, Holland *et al.* 1979). Haemorrhage is controlled by insertion of sterile cotton pellets slightly moistened with sterile saline. A dressing of calcium hydroxide is placed over the radicular pulp tissue. A creamy mix of zinc oxide–eugenol cement is used to seal the dressing in place, followed by a sound restoration designed to protect the cement base and prevent contamination (Case No. 2, Figs. 5–8).

It is obvious that not all cases indicated for partial pulpectomy will display an intact odontoblastic membrane. Circumstances surrounding each individual case must be taken into account by the practitioner, i.e. large class III coronal fracture, exposure upon removal of caries, etc., and appropriate clinical judgment exercised in determining the proper course of treatment. In all cases, though, every effort must be made to preserve the integrity of the apical radicular pulp, even to the point of performing a partial pulpectomy (deep pulpotomy) in which the coronal to mid-portion of the radicular pulp is removed in an attempt to eliminate contaminated and/or diseased tissues.

Discussion

Once the integrity of the pulp has been seriously compromised and vital pulp treatment has been necessary, it may be impossible to know the capability of the pulp to respond to treatment, especially if the tooth has a history of previous or chronic insult. Therefore, close patient follow-up is necessary in all cases of vital pulp treatment.

Any signs of pulpal necrosis as might be evidenced by clinical symptoms of swelling, coronal discoloration, tenderness to percussion, or sensitivity to thermal changes may indicate that apexogenesis will not occur. Radiographic comparison of the treated tooth with surrounding teeth serves as a biological clock used to determine if apical closure is occurring. If closure does not occur relative to the surrounding dentition, or if symptoms of pulpal degeneration or necrosis appear, then apexification pro-

---

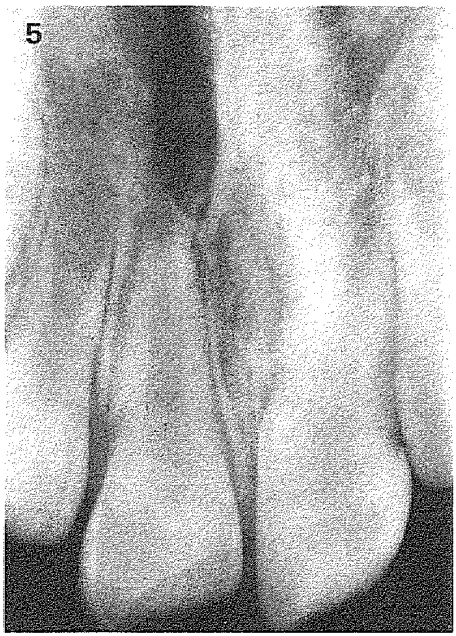
Case No. 1

Fig. 1. A class II coronal fracture evident in the upper central incisor of a 6-year-old male patient. Note the open-wide apex and immature development of the root length. Calcium hydroxide – saline paste was placed over the exposed dentine, followed by a composite restoration.

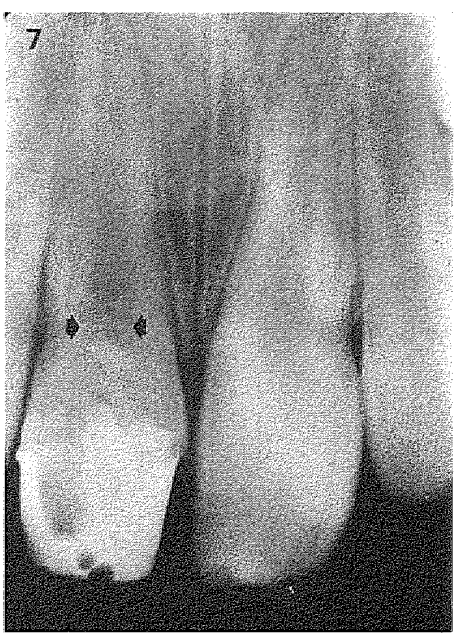
Fig. 2. Six-month recall evaluation demonstrates continued root length development and initial attempts at apical closure.

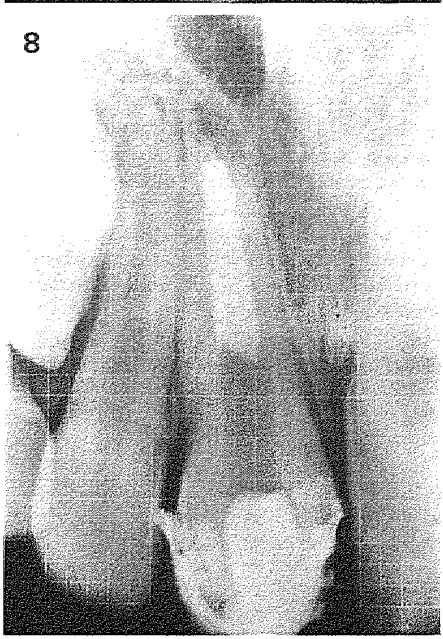
Fig. 3. A 12-month recall demonstrates continued root length development and almost complete apical closure.

Fig. 4. A 27-month recall demonstrates complete root length and apical formation. All pulp tests indicate the presence of a normal, intact, uninflamed pulp.


5


6


7


8

cedures are initiated (Gutmann & Heaton 1981).

During the course of patient observation, reparative dentine may form adjacent to the area where pulp capping or pulpotomy was performed. Although this is indicative of pulpal repair, the prime focus of attention must be placed on the closure of the root apex.

As opposed to apexification procedures which attempt to induce apical closure, apexogenesis procedures are designed to allow for increased root growth in addition to normal apical formation. It is possible in cases where the radicular pulp appears clinically vital, yet may be compromised by tissue or microbial degradation products, that the root end may close rapidly without any appreciable root lengthening. In either case, any anticipated endodontic procedure can be successfully completed.

Once apexogenesis has been achieved, a controversy exists as to the need for further pulpal treatment. Bodenham (1967) and Krakow *et al.* (1977) are of the opinion that complete root canal treatment, subsequent to a partial pulpectomy which has resulted in completion of root formation, is indicated only when a post and core is required for adequate restoration of the crown of the tooth (both anterior and posterior).

Dannenberg (1974), Kopel (1976), Goldman (1974) and Langeland *et al.* (1971, 1977) strongly advocate that following closure of the apex, a complete pulpectomy be performed to forestall root canal calcification, pulpal degeneration, or internal resorption. In either case, a sound restoration must be placed to prevent occlusal leakage, to protect the tooth from possible fracture, and to maintain an intact arch, especially in the mixed dentition.

Acknowledgements

The authors would like to thank Dr Stanley H. Klein for the use of the cases presented and Dr Stephen R. Warren for assistance in the preparation of the manuscript.

References

BERK, H. & KRAKOW, A.A. (1972) A comparison of the management of pulpal pathosis in deciduous and permanent teeth. *Oral Surgery, Oral Medicine and Oral Pathology*, **34**, 944–955.

BERK, H., KRAKOW, A.A. & STANLEY, H.R. (1975) Clinical situations in which amputation is preferred to pulp capping because of biologic considerations. *Journal of the American Dental Association*, **90**, 801–805.

BODENHAM, R.S. (1967) The prognosis for vital pulpotomy of traumatised permanent incisors. *Dental Practitioner and Dental Record*, **17**, 327–330.

BRITTON, A.S. (1976) Total coronal pulpotomy of the vital permanent molar. *Proceedings of the British Paedodontic Society*, **6**, 15–18.

CANBY, C.P. & BURNETT, G.W. (1963) Clinical management of deep carious lesions. *Oral Surgery, Oral Medicine and Oral Pathology*, **16**, 999–1011.

CORPRON, R.E. & DOWSON, J. (1970) Pulpal therapy for the traumatized immature permanent anterior tooth. *Journal of the Michigan Dental Association*, **52**, 224–230.

CVEK, M. (1978) A clinical report on partial pulpotomy and capping with calcium hydroxide in permanent incisors with complicated crown fracture. *Journal of Endodontics*, **4**, 232–237.

DANNENBERG, J.L. (1974) Pedodontic endodontics. *Dental Clinics of North America*, **18**, 367–377.

DiMAGGIO, J.J. & HAWES, R.R. (1963) Continued evaluation of direct and indirect pulp capping. *Journal of Dental Research*, **41**, 38 (abstract).

DORFMAN, A., STEPHAN, R.M. & MUNTZ, J.A. (1943) *In vitro* studies of carious dentine. II. Extent of infection in carious lesion. *Journal of the American Dental Association*, **30**, 1901–1904.

Case No. 2

Fig. 5. A class III coronal fracture with a pulp exposure on a maxillary central incisor is evident on an 8-year-old male patient. A coronal pulpotomy was performed using a calcium hydroxide saline paste.

Fig. 6. Three months following the pulpotomy. The patient was asymptomatic.

Fig. 7. Six months following pulpotomy the root apex appears to be closing normally relative to the adjacent central incisor. Note the coronal calcific bridge formation (*arrow*).

Fig. 8. Twenty-six months following the initial pulpal therapy. Root canal therapy was accomplished without complication.

FRANKL, S.N. (1972) Pulp therapy in pedodontics. *Oral Surgery, Oral Medicine and Oral Pathology*, **34**, 293–309.

GOLDMAN, M. (1974) Root-end closure techniques including apexification. *Dental Clinics of North America*, **18**, 297–308.

GUTMANN, J.L. & HEATON, J.F. (1981) Management of the open (immature) apex. 2. Non-vital teeth. *International Endodontic Journal*, **14**, 173–178.

HARTSOOK, J.T. (1966) Pulpal therapy in primary and young permanent teeth. *Dental Clinics of North America*, **10**, 377–389.

HELD-WYDLER, E. (1964) 'Natural' (indirect) pulp capping. *Journal of Dentistry for Children*, **31**, 107–113.

HOLLAND, R., deSOUZA, V., deMELLO, W., NERY, M.J., BERNABE, P.F.E. & OTOBONI FILHO, J.A. (1979) Permeability of the hard tissue bridge formed after pulpotomy with calcium hydroxide: a histologic study. *Journal of the American Dental Association*, **99**, 472–475.

KALNINS, V. & FRISBIE, H.E. (1960) Effect of dentine fragments on the healing of the exposed pulp. *Archives of Oral Biology*, **2**, 96–103.

KING, J.B., CRAWFORD, J.J. & LINDAHL, R.L. (1965) Indirect pulp capping: a bacteriologic study of deep carious dentine in human teeth. *Oral Surgery, Oral Medicine and Oral Pathology*, **20**, 663–671.

KOPEL, H.M. (1976) Pediatric endodontics. In *Endodontics* (eds J.I.Ingle and E.E.Beveridge), Chap. 17. Lea & Febiger, Philadelphia.

KRAKOW, A.A., BERK, H. & GRON, P. (1977) Therapeutic induction of root formation in the exposed incompletely formed tooth with vital pulp. *Oral Surgery, Oral Medicine and Oral Pathology*, **43**, 755–765.

LANGELAND, K., DOWDEN, W.E., TRONSTAD, L. & LANGELAND, L. (1971) Human pulp changes of iatrogenic origin. *Oral Surgery, Oral Medicine and Oral Pathology*, **32**, 943–980.

LANGELAND, K. & LANGELAND, L.K. (1968) Indirect capping and the treatment of deep carious lesions. *International Dental Journal*, **18**, 326–380.

LANGELAND, K., LANGELAND, L. & ANDERSON, D. (1977) Corticosteriods in dentistry. *International Dental Journal*, **27**, 217–251.

LAW, D.B. (1961) Prevention and treatment of traumatized permanent anterior teeth. *Dental Clinics of North America*, **5**, 615–629.

LAW, D.B. & LEWIS, T.M. (1961) The effect of calcium hydroxide on deep carious lesions. *Oral Surgery, Oral Medicine and Oral Pathology*, **14**, 1130–1137.

MASSLER, M. (1967) Preventive endodontics: vital pulp therapy. *Dental Clinics of North America*, **11**, 663–673.

MASSLER, M., BERMAN, D.S. & JAMES, V. (1957) Pulp capping and pulp amputation. *Dental Clinics of North America*, **1**, 789–804.

NAIDORF, I.J. (1970) Management of the young, pulp-involved, vital tooth. *Annals of Dentistry*, **29**, 23–30.

PARIKH, S.R., MASSLER, M. & BAHN, A. (1963) Micro-organisms in active and arrested carious lesions of dentine. *New York State Dental Journal*, **29**, 347–355.

REED, M.W. (1977) Pulp therapy for primary and young permanent teeth. In *Clinical Dentistry* (ed. J. W. Clark), Chap. 18. Harper & Row, Hagerstown.

SELTZER, S. & BENDER, I.B. (1975) Pulp capping and pulpotomy. In *The Dental Pulp, Biologic Considerations in Dental Procedures* (eds S. Seltzer and I. B. Bender), Chap. 14. J. B. Lippincott, Philadelphia.

SHIERE, F.R., FRANKL, S.N. & FOGELS, H.R. (1961) Pulpal therapy for primary and immature permanent teeth. *Dental Clinics of North America*, **5**, 639–648.

SHOVELTON, D.S. (1968) A study of deep carious dentine. *International Dental Journal*, **18**, 392–405.

STARKEY, P.E. (1968) Management of deep caries of pulpally involved teeth in children. In *Current Therapy in Dentistry* (eds H. M. Goldman *et al.*), Vol. 3. C. V. Mosby, St. Louis.

WINTER, G.B. (1977) Endodontic therapy of traumatised teeth in children. *International Dental Journal*, **27**, 252–262.