Invasive Cervical Resorption and Associated Endodontic Research

APPENDICES

GEOFFREY SINCLAIR HEITHERSAY

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APPENDIX 1

Contents

Chronological list of publications.

1. HEITHERSAY, G.S. (1959)
A dental survey of Aborigines at Haast' Bluff, Central Australia.
Med. J. Aust 1:721-729.

2. HEITHERSAY, G.S. (1960)
Attritional values for Australian Aborigines, Haast's Bluff.
Aust. Dent. J. 5:84-88.

3. HEITHERSAY, G.S. (1961)
Further observations on the dentition of the Australian Aborigines at Haast's Bluff.
Aust Dent. J. 6:18-28.

4. HEITHERSAY, G.S. and BJERKEN, E. (1962)
The incidence of Staphylococcus Albus and Steptococcus Salivarius in root canal cultures.
Odont. Revy 13:152-157.

5. HEITHERSAY, G.S. and BRANNSTROM, M. (1963)
Observations on heat-transmission experiments with dentin.
1 Laboratory Study.
J.Dent.Res. 42:1140-1145.

6. HEITHERSAY, G.S. (1965)
Pulp reactions following partial pulpectomy.
M.D.S. Thesis, University of Adelaide.

7. HEITHERSAY, G.S (1970)
Stimulation of root formation in incompletely developed pulpless teeth.
Oral.Surg 29:620-630.

8. HEITHERSAY, G.S. (1970)
Periapical repair following conservative endodontic therapy.
Aust. Dent. J. 15:511-518.

9. HEITHERSAY, G.S. (1973)
Combined endodontic-orthodontic treatment of transverse root fractures in the region of the alveolar crest.
Oral. Surg. 36:404-415.

10. SMALES, R.J., MAKINSON, O.F. and HEITHERSAY, G.S. (1974)
An analysis of endodontic treatment at a dental school.
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11. HEITHERSAY, G.S. (1975)
Replantation of avulsed teeth. A review.
Aust. Dent. J. 20:63-72.

12. HEITHERSAY, G.S. (1975)
Calcium hydroxide in the treatment of pulpless teeth with Associated pathology.
J Br. Endod. Soc 8:74-93.

13. HEITHERSAY, G.S. and MAYNE, J.R. (1975)
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14. HEITHERSAY, G.S. (1977)
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15. HEITHERSAY, G.S. and MOULE, A.J. (1982)
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Aust. Dent J. 27:368-376.

16. HEITHERSAY, G.S. (1985)
Endodontic treatment in Australia.
Int. Endod. J. 17:125-138.

17. HEITHERSAY, G.S. (1985)
Clinical endodontic and surgical management of tooth and associated bone resorption.
Int. Endod. J 18:72-79

18. HEITHERSAY, G.S. (1986)
Tissue response of the rat to trichloracetic acid.
J.Dent.Res. 66:822. Abs. 37.

19. HEITHERSAY, G.S., WILSON, D.F. (1988)
Tissue responses in the rat to trichloracetic acid-
An agent used in the treatment of invasive cervical resorption.
Aust. Dent. J. 33:451-461.

20. PIERCE, A.M., HEITHERSAY, G.S. and LINDSKOG, S. (1988)
Evidence for direct inhibition of dentinoclasts by a corticosteroid/antibiotic endodontic paste.
Endod. Dent. Traumatol. 4:44-45.

21. ABBOTT, P.V., HEITHERSAY, G.S. and HUME, W.R. (1988)
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Endod. Dent. Traumatol. 4:55-62.

22. ABBOTT, P.V., HUME, W.R., and HEITHERSAY, G.S. (1989)
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23. ABBOTT, P.V., HUME, W.R., and HEITHERSAY, G.S. (1989)
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25. TAYLOR, M.A., HUME, W.R., and HEITHERSAY, G.S. (1989)
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26. HEIJKOOP, P.S., HEITHERSAY, G.S. and MAKINSON, O.F. (1990)
Industrial Materials as Temporary Endodontic Access Seals.
J.Dent.Res. 4:935. Abs. 69.

27. CARDACHI, S.C., PIERCE, A.M., WIEBKIN, O.W. and HEITHERSAY, G.S. (1990)
Calcitonin Therapy: The Tooth is an Instrinsic Slow-Release Mechanism.
J.Dent.Res. 5:934. Abs. 69.

28. ABBOTT, P.V., HEIJKOOP, P.S., CARDACHI, S.C, HUME, W.R., HEITHERSAY, G.S. (1991)
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29. REID, R.J., WILSON, D.F., HEITHERSAY, G.S. and HEIJKOOP, P.S. (1992)
Tissue responses to hydron assessed by intraosseous implantation.
Int. Endod. J. 25:192-198.

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Tissue responses to Hydron, assessed by intramuscular implantation.
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31. MCNAMARA, J.R., HEITHERSAY, G.S. and WEIBKIN, O.W. (1992)
Cell responses to Hydron by a new in-vitro method.
Int. Endod. J. 25:205-212.

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A five - year study of Hydron root canal fillings.
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33. DAHLSTROM, S.W., BRIDGES, T.E. & HEITHERSAY G.S. (1993)
Hydroxyl Radical Activity in Bleached Root-filled Teeth.
J. Dent. Res. 676 Abs. 90.

34. HEITHERSAY, G.S., DAHLSTROM, S.W., & MARIN P.D.(1993)
Incidence of Invasive Cervical Resorption in Bleached Root-filled Teeth.
J. Dent. Res 676 Abs. 89.

35. MARIN P.D., BARTOLD, P.M. & HEITHERSAY G.S. (11993)
Histological Evaluation of Teeth Stained in vitro with Blood.
J. Dent. Res 676 Abs. 91.

36. HEITHERSAY, G.S. and HIRSCH, R.S. (1993)
Tooth discoloration and resolution following a luxation injury:
Significance of blood pigment in dentin to laser Doppler flowmetry readings.
Quint. Int 24:9;669-676

37. HEITHERSAY, G.S., DAHLSTROM S.W. and MARIN P.D. (1994)
Incidence of invasive cervical resorption in bleached root-filled teeth.
Aust Dent. J 39:2 ; 82-87.

38. HEITHERSAY. G.S. (1994)
External Root Resorption.
Ann. R. Aust. Coll. Dent. Surg 12: 46-59.

39. WEIBKIN O.W., CARDACHI S.C.,HEITHERSAY G.S. & PIERCE A.M. (1996)
Therapeutic delivery of calcitonin to inhibit external Inflammatory root resorption.
I. Diffusion kinetics of calcitonin through the dental root.
Endod Dent Traumatol 12:265-271.

40. WEIBKIN O.W., CARDACHI S.C., HEITHERSAY G.S. & PIERCE A.M. (1996)
Therapeutic delivery of calcitonin to inhibit external Inflammatory root resorption.
II. Influence of calcitonin in binding to root mineral.
Endod Dent Traumatol 12:272-276.

41. DAHLSTROM SW, HEITHERSAY GS, BRIDGES TE. (1997)
Hydroxyl radical activity in bleached root-filled teeth.
Endod Dent Traumatol 13:119-25.

42. MARIN PD, BARTOLD PM, HEITHERSAY GS.(1 997)
Tooth discoloration by blood:an in vitro biochemical study.
Endod Dent Traumatol 13:132-8.

43. MARIN PD, HEITHERSAY GS, BRIDGES TE. (1998)
A quantative comparison of traditional and non-peroxide bleaching agents.
Endod Dent Traumatol 14:64-67.

44. HEITHERSAY GS. (1999)
Clinical, radiologic, and histopathologic features of invasive cervical resorption.
Quintessence Int 30:27-37.

45. HEITHERSAY GS. (1999)
Invasive cervical resorption: An analysis of potential predisposing factors.
Quintessence Int 30:83-95

46. HEITHERSAY GS. (1999)
Treatment of invasive cervical resorption:
An analysis of results using topical application of trichloracetic acid,curettage and restoration.
Quintessence Int 30:96-110

47. HEITHERSAY GS (1999)
Invasive cervical resorption following trauma.
Australian Endo. Jour.25:2;79-86.

APPENDIX 2

Contents

Volume 2

These publications are included in the print copy

of the thesis held in the University of Adelaide Library.

Paper 1

Heithersay, G. S. (1959). A dental survey of the Aborigines at Haast's Bluff, Central Australia. *The Medical Journal of Australia, 1*(22), 721-729.

Paper 2

Heithersay, G. (1960). Attritional values for Australian aborigines, Haast's Bluff. *Australian Dental Journal, 5*(2), 84-88. https://doi.org/10.1111/j.1834-7819.1960.tb03156.x

Paper 3

Heithersay, G. (1961). Further observations on the dentition of the Australian aborigine at Haast's Bluff. *Australian Dental Journal, 6*(1), 18-28. https://doi.org/10.1111/j.1834-7819.1961.tb03196.x

Paper 4

Heithersay, G. S., & Bjerken, E. (1962). The incidence of Staphylococcus albus and Streptococcus salivarius in root canal cultures. *Odontologisk Revy, 13*(2), 152-157.

Paper 5

Heithersay, G., & Brännström, M. (1963). Observations on Heat-Transmission Experiments with Dentin. 1. Laboratory Study. *Journal of Dental Research, 42*(5), 1140-1145.

Paper 6

Included

Paper 7

Heithersay, G. (1975). Calcium hydroxide in the treatment of pulpless teeth with associated pathology. *Journal of the British Endodontic Society, 8*(2), 74-93. https://doi.org/10.1111/j.1365-2591.1975.tb01000.x

Paper 8

Included

Paper 9

Heithersay, G., & Moule, A. (1982). Anterior subgingival fractures: A review of treatment alternatives. *Australian Dental Journal, 27*(6), 368-76. https://doi.org/10.1111/j.1834-7819.1982.tb02467.x

Paper 10

Included

Paper 11

Heithersay, G., & Hirsch, R. (1993). Tooth discoloration and resolution following a luxation injury: Significance of blood pigment in dentin to laser Doppler flowmetry readings. *Quintessence International, 24*(9), 669-76.

Paper 12

Smales, R., Makinson, O., & Heithersay, G. (1974). An analysis of endodontic treatments at a dental school. *Australian Dental Journal, 19*(1), 25-31. https://doi.org/10.1111/j.1834-7819.1974.tb05015.x

Paper 13

Heithersay, G., & Mayne, J. (1975). Endodontic education. *Australian Dental Journal, 20*(5), 311-5. https://doi.org/10.1111/j.1834-7819.1975.tb05078.x

STIMULATION OF ROOT FORMATION IN INCOMPLETELY DEVELOPED PULPLESS TEETH

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Stimulation of root formation in incompletely developed pulpless teeth

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Treatment of teeth in which the dental pulp has become totally necrotic before completion of root development is difficult if the operator depends on a coronal approach and attempts to seal the patent canal via the root. Because of this, many endodontists have favored a surgical approach and have endeavored to seal the apex by using a retrograde root-filling material.

However, surgical management is not entirely satisfactory because of inherent difficulties in the operative procedure and because of the physical and psychologic trauma to a young patient. Furthermore, a tooth treated in this manner often has inadequate root length to withstand masticatory forces, and the periapical tissues may fail to adapt to the wide and relatively irregular surface of the retrograde root-filling material. Thus, the long-term prognosis is generally doubtful.

In order to overcome the difficulties just mentioned, some writers[1-4] have essayed a conservative approach and have used calcium hydroxide, either alone or in combination with other agents, to stimulate further root development. To date there have been few case reports, and as yet the results of a histologic examination have not been published.

The purpose of this article is to present case reports of twenty-one teeth which have been treated by a conservative method and to provide details of histologic examination of a tooth which received conservative treatment but which had to be extracted later because of a vertical root fracture. In presenting this series, I hope to provide further support for conservative treatment of the pulpless "blunderbuss" incisor.

MATERIALS AND METHODS

A. Clinical series

The patients in the present series were referred for endodontic treatment of teeth which had suffered pulp death and consequent periapical involvement

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at a stage of incomplete root development. A total of twenty-one teeth were treated in seventeen patients whose ages ranged from 7 to 11 years.

The causes of pulp death were trauma (eighteen teeth), caries (one tooth), and deep palatal invagination with subsequent bacterial invasion (two teeth).

All teeth had evidence of periapical pathology on radiographic and clinical grounds. In four cases (Teeth A3, A8, A9, and A11) the patients had acute periapical osteitis and associated cellulitis of the lip and face.

Clinical procedure

In each case, the root canal was sterilized by routine endodontic procedures. Mild medicaments were used for irrigation and root canal dressing. The solution used for both purposes in this series was an aqueous solution of 0.03 per cent chlorhexidine and 0.3 per cent cetrimide (Savlon). After sterilization of the canal had been achieved, the walls were dried with a cotton pellet attached to the tip of a large file or with the blunt ends of paper points. Calcium hydroxide and methyl cellulose (Pulpdent) paste was then introduced by means of a Pulpdent syringe with a Luer-Lok needle attached. Excess paste was removed from the pulp chamber, and the coronal opening was sealed with Cavit and amalgam. Patients were recalled after 1 month and 3 months, and at 6-month intervals thereafter. The observation times ranged from 14 to 75 months.

B. Histologic specimen

A central incisor tooth treated by the above method became available for histologic examination when a vertical root fracture made extraction necessary. The patient had been treated at the Dental Department of the Royal Adelaide Hospital in April, 1965. He had failed to report for follow-up examinations but returned in pain in May, 1968. The tooth was extracted, decalcified in a formic acid–sodium formate solution, and serially sectioned at 7 microns. Sections were stained with either hematoxylin and eosin or Mayer's hematoxylin and eosin.

RESULTS

Clinical series

The results of treatment are summarized in Table I.

Representative cases (Teeth A9, A13, A17, and A7) are shown in Figs. 1 through 8. In each instance the case histories are included in the legends.

Of the twenty-one teeth treated by this method, only Teeth A6 and A18 (Figs. 5 and 6) did not show evidence of further root development. The observation times for these two cases were 55 months and 18 months, respectively. Periapical repair was complete in Tooth A6 and, on clinical investigation, viable tissue was present within the root canal. In Tooth A18 there was a breakdown of the coronal seal after 10 months, and bacterial contamination resulted. Subsequently, the tooth was re-treated, and the 18-month follow-up examination disclosed positive evidence of periapical repair, although this was not complete. No further root development could be demonstrated at this stage.

Of the nineteen teeth which demonstrated further root development, five

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Table I. Summary of results of treatment of incompletely developed teeth using a

Tooth serial No.	Status: Age (yr.)	Status: Tooth	Status: Observation time (mo.)	Periapical repair: Nil	Periapical repair: Partial	Periapical repair: Complete
A1	8½	2	75			×
A2	8	1	63			×
A3	8	1	56			×
A4	8½	1	56			×
A5	8	1	55			×
A6	8	1	55			×
A7	7	1	43			×
A8	8	1	36			×
A9	8	1	29			×
A10	11	2	29			×
A11	8	1	28			×
A12	8	1	27			×
A13	11	2	27			×
A14	11	2	27			×
A15	8	1	23			×
A16	7	1	23			×
A17	7	2	18			×
A18	7	1	18		×	
A19	7	1	18			×
A20	7	1	14			×
A21	11	5	14			×
Totals					1	20

showed partial apical root formation and fourteen showed complete apical root formation. In all cases, root formation had proceeded to such a stage that the apical opening was convergent rather than divergent.

There did not appear to be any difference in the reparative response in those cases in which the patient presented in an acute inflammatory state (Teeth A3, A8, A9, and A11) and the remaining cases in which there were associated chronic periapical lesions.

A definite fine root canal could be observed in all teeth that had progressed to completion of root formation. No complete calcific barrier could be observed at the coronal extremity of the apical canal in these cases. In four teeth permanent root fillings of gutta-percha and AH-26 were placed after apical development was complete. In each case bleeding tissue was encountered within the root canal in the apical region.

Histologic specimen

Histologic examination revealed that the newly deposited apical tissue not only encircled but extended into the original root. The tissue forming the apex of the specimen consisted of remnants of pulp tissue, dentine, and thick deposits of cementum with attached periodontal membrane (Fig. 9).

A buckling of the original root apex was evident (framed areas in Fig. 9

calcium hydroxide and methylcellulose paste

Results					
Root development			*Clinical and radiographic assessment of result*		
Nil	*Partial*	*Complete*	*Failure*	*Doubtful*	*Success*
		×			×
		×			×
		×			×
		×			×
		×			×
		×			
		×			
		×			
	×				
		×			
		×			
		×			×
	×				×
		×			×
×					
	×				×
	×				×
					×
2	5	14		2	19

and Figs. 10 and 11). In the region of this buckling there was evidence of resorption on the outside of the root. This had subsequently been repaired by the deposition of cellular and acellular cementum which also extended in thick layers over the entire apical plug of calcific tissue. The major part of this apical plug consisted of interglobular dentine. In some areas there was a tendency toward regular tubule formation, but in the region of the outward buckling of the original root the dentine was of a particularly irregular character.

Within the old canal, two distinct layers had been deposited. There had been some separation of these layers during the histologic preparation and thus slight artifacts were evident (Figs. 9 and 10). Both layers which extended 3 to 4 mm. into the old canal consisted of interglobular dentine, but the first layer was thin and seemed less tubular than the thicker superimposed layer. No calcific barrier bridging the original canal was evident at the coronal extremity of these layers.

A fine root canal was present in the newly formed apical region. This contained tissue resembling the dental pulp, but infiltration with chronic inflammatory cells had occurred. No normal pulp tissue could be observed in the junction between the fine apical canal and the wide original canal. A lateral canal containing chronically inflamed pulp tissue was present in this region. Scattered carbon artifacts were present in many sections as a result of the pencil lead which had been inserted into the canal by the patient.

Fig. 1

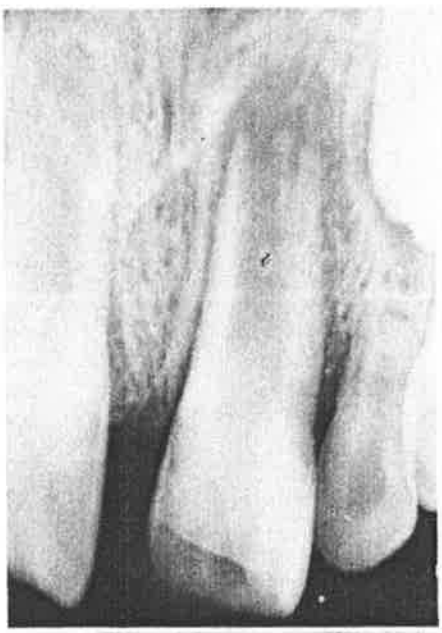

Fig. 2

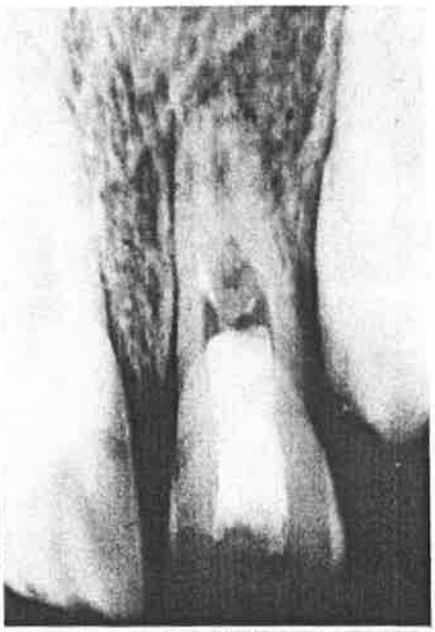

Fig. 3

Fig. 4

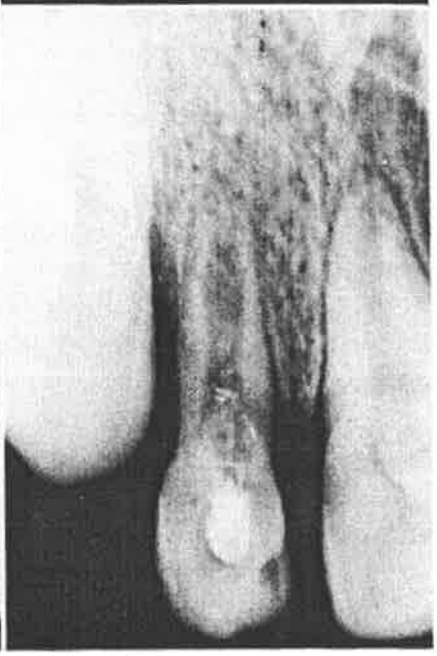

Fig. 1. **Tooth A9. Upper left central incisor of an 8-year-old boy. The patient, who presented with an acute periapical osteitis, gave a history of a blow 2 months earlier. A radiolucent periapical lesion was evident. Root treatment was followed by the insertion of calcium hydroxide-methylcellulose paste.**

Fig. 2. **Tooth A9. Two years later the tooth showed considerable root development and periapical repair.**

Fig. 3. **Tooth A13. Upper right lateral incisor of a 10-year-old girl. The cause of the chronic periapical osteitis was a deep palatal invagination of the cingulum with subsequent intrapulpal bacterial invasion. A periapical radiolucency was evident (see Fig. 1).**

Fig. 4. **Tooth A13. One year later, following the placement of a calcium hydroxide and methylcellulose paste, apical development and periapical repair have occurred.**

Fig. 5

Fig. 6

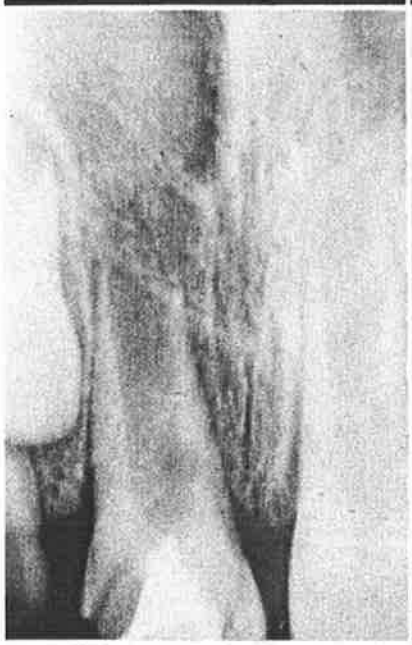

Fig. 7

Fig. 8

Fig. 5. Teeth A17 and A18. A 7-year-old girl with a history of traumatic injury to the upper right central and lateral incisors 2 months previously. On initial examination, both teeth were pulpless and there was an acute periapical osteitis associated with the lateral incisor. Both teeth were treated and filled with calcium hydroxide and methylcellulose paste. The coronal seal in the central incisor was deficient, and contamination of the canal occurred after 4 months. Subsequently, the canal was re-treated and filled with the same paste.

Fig. 6. Teeth A17 and A18. Ten months later complete root development was apparent in the upper right lateral incisor, and there were signs of periapical repair in the central incisor.

Fig. 7. Tooth A7. Upper right central incisor in an 8-year-old boy. There was a chronic periapical osteitis, with an associated draining sinus. The tooth was treated and filled with the calcium hydroxide and methylcellulose paste.

Fig. 8. Tooth A7. The patient returned 2½ years later, having failed to keep appointments for follow-up examinations. The coronal seal had been lost; caries and a vertical root fracture with an associated lesion on the mesial aspect of the root were present. In addition, the patient had pushed the lead of a pencil into the canal. Considerable apical root development had occurred since the initial treatment. This tooth was extracted and prepared for histologic examination.

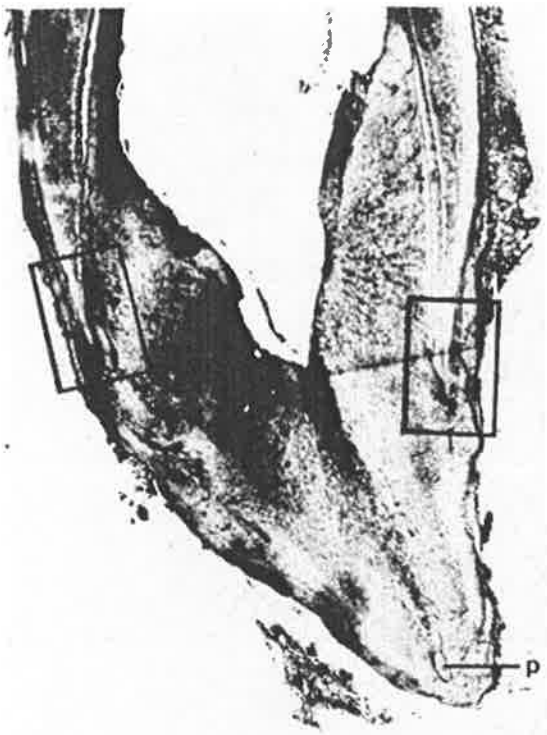

Fig. 9. Tooth A8. Histologic section stained with Mayer's hematoxylin and eosin stain (magnification, x40). Within the framed areas can be seen the buckled outline of the original root apex. Two layers of interglobular dentine can be seen extending into the old canal and lining it. Only a small amount of pulp tissue *(p)* can be seen in this section (see Figs. 12 and 13).

DISCUSSION

The clinical series described here provides support for conservative endodontic treatment in incompletely developed teeth where the aim is stimulation of further root formation.

Clinical evaluation, based on evidence of periapical repair and root development, revealed that in nineteen of the twenty-one cases treatment was considered successful. Two cases (Teeth A6 and A18) were classified as doubtful although periapical repair was complete in one (Tooth A6) and was progressing satisfactorily in the other (Tooth A18). No tooth in the present material was considered to represent a treatment failure.

The clinical features of the root formation in the present series were essentially the same as those in previously published case reports, although Steiner and associates[4] indicated that a definite bridge or calcific barrier was present. They reported that a permanent root filling could be placed without any risk of extending the root-filling material apically. In teeth with apical development a definite fine apical canal could be seen radiographically, but there was no definite apical barrier. The clinical observation of bleeding tissue within the canals of those four teeth in which roots were filled offers additional evidence that no calcific barrier existed between the fine apical canal and the original wider canal.

Fig. 10

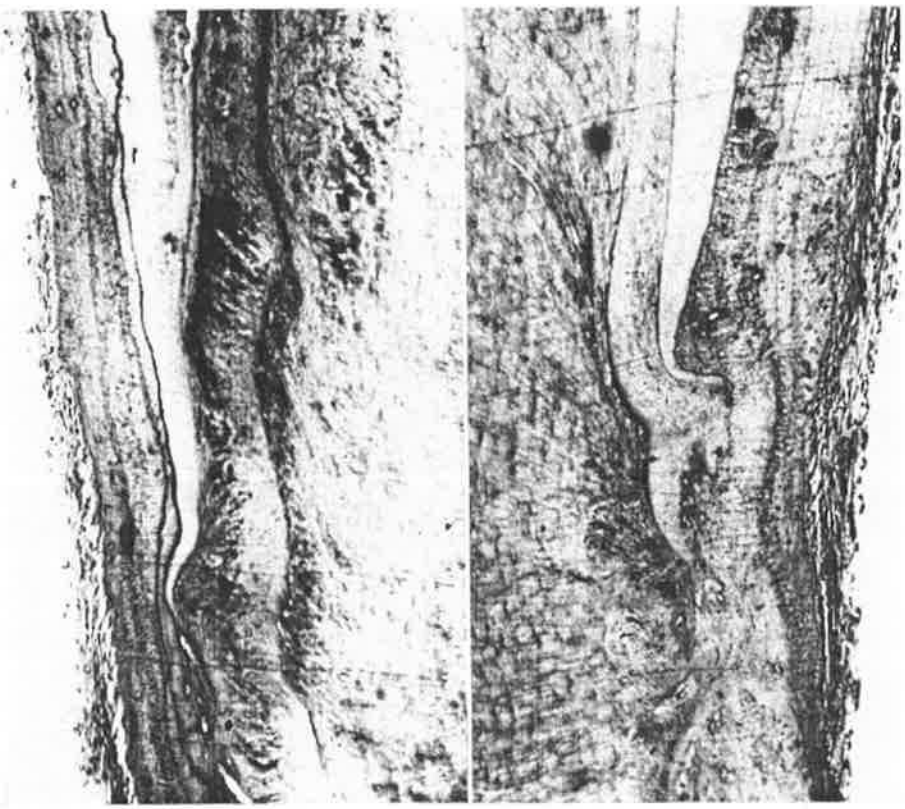

Fig. 11

Fig. 10. Tooth A8. Framed area from the left side of section shown in Fig. 9 (magnification, ×100) showing the region of buckling of the original root and surrounding calcific changes. Resorption of the original root surface in this junction has been repaired by thick deposits of cellular and acellular cementum, while on the canal side two layers of interglobular dentine can be seen extending into the old canal. A separation artifact is present superiorly.

Fig. 11. Tooth A8. Framed area from the right side of section shown in Fig. 9 (magnification, ×100). Regions similar to those shown in Fig. 10 can be seen. The two layers of interglobular dentine are well defined, the thinner deposit being less tubular than the overlying layer.

The histologic specimen similarly did not demonstrate any calcified barrier between the newly formed apical plug and the old canal. Indeed, in this histologic specimen, the absence of such a barrier can be assumed to be the reason for the unimpeded bacterial invasion which followed the breakdown of the coronal seal. This would account for the chronic inflammatory changes observed in the apical pulp, but it would seem reasonable to assume that prior to bacterial invasion this tissue had been in a healthy state.

The histologic findings show that apical development had occurred by the formation of relatively normal dental tissues of pulp, dentine, and cementum. Not only was there development apically, but there was also deposition of new dentine within and also on the surface of the original canal, indicating that the replacement of the calcium hydroxide by ingrowing pulp tissue may have been a continuing process.

The repair reactions that have been observed are interesting, and some speculation can be made as to their nature. Epithelium is thought to be resistant to inflammatory changes. Thus, it is possible that in these cases Hertwig's

Fig. 12

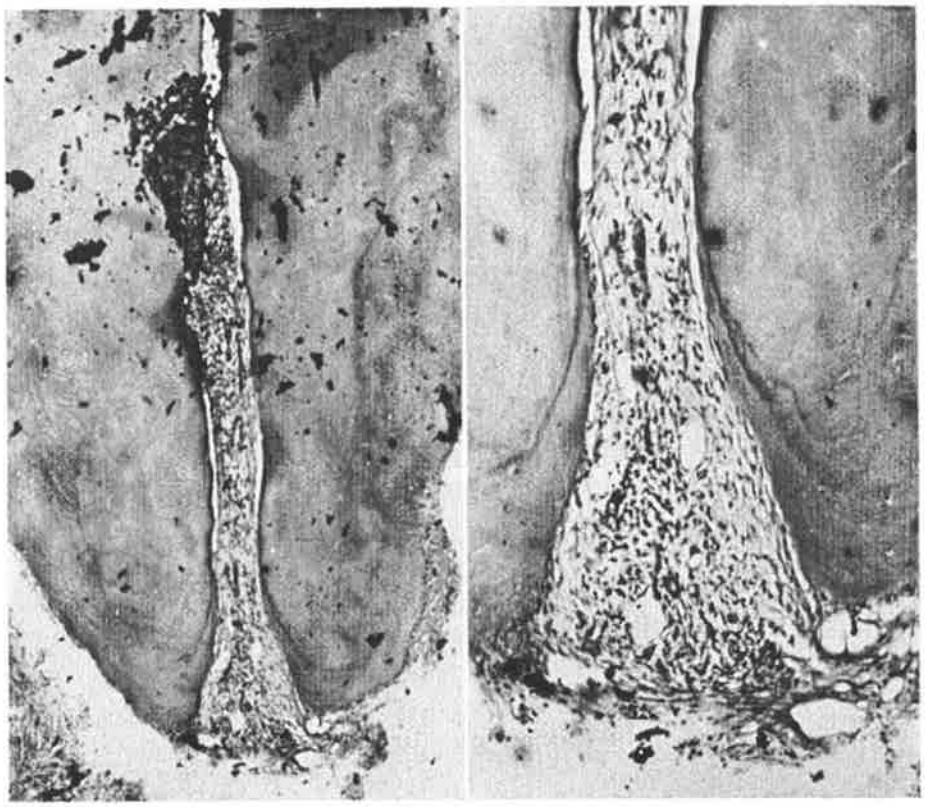

Fig. 13

Fig. 12. Section through the root canal in the apical region. (Hematoxylin and eosin stain. Magnification, ×40.) Pulp contains many chronic inflammatory cells following contamination of the root canal with bacteria. Black carbon artifacts from the lead of a pencil inserted into the canal by the patient are scattered over the field. Thick apical deposits of cementum can be observed.

Fig. 13. Higher magnification (×100) showing chronically inflamed pulp tissue at the apical foramen.

sheath can survive and so remain able to continue its role of organization of root development when the inflammatory process is eliminated. Accordingly, if bacteria are removed and a material which favors repair of the periapical tissues is subsequently introduced into the root canal, Hertwig's sheath may be expected to continue more or less in its normal fashion. The cells in the periapical region of an incompletely developed tooth may perhaps be considered to be pluripotential and thus subject to differentiation into cells which can form normal dental tissues after the inflammatory reaction resolves.

The material used in filling the root canal may aid the process of differentiation. Calcium hydroxide has been considered by some workers[5] to have an osteogenic potential. However, this same development has been reported by Cooke and Rowbotham,[6] who used an antiseptic paste containing zinc oxide and eugenol, and also by Ball,[7] who used an antibiotic paste. Calcium hydroxide may exert a favorable effect by virtue of its high alkalinity altering the pH of the region, or perhaps the calcium ions may increase the local capillary permeability, and this may favor repair. Histochemical studies may help to solve the mode of action of calcium hydroxide in its present application.

The absence of an apical calcific barrier and the presence of ingrowing pulp

tissue, as shown by the clinical and histologic material, pose additional clinical problems. If a permanent root filling of gutta-percha and a suitable sealer are inserted directly onto the apical pulp tissue, an adverse pulpal response can be expected. Should a permanent root filling be necessary for restorative purposes, the ingrowing pulp tissue can be removed down to the level of the entrance of the fine apical canal and the pulp wound dressed with a thin layer of calcium hydroxide. The rest of the canal can then be filled with gutta-percha and a sealing agent. The pulp remnant may then undergo the normal repair reactions which follow partial pulpectomy using calcium hydroxide.[8-11] An alternative and probably safer method would be to extend the root filling to the apex of the tooth after removal of the pulp tissue and widening of the fine apical canal.

It is hoped that most of the teeth in the present series will not require permanent root fillings for some years. Further observation may reveal additional calcific changes and furnish material for subsequent reports.

Conservative treatment of incompletely developed pulpless teeth with calcium hydroxide provides a simple, nontraumatic solution to an otherwise difficult problem. The method has the advantage that greater root length is attained, with its obvious advantages in the long-term stability of the tooth. Once root development has been completed, an orthodox root filling can be placed without technical difficulty.

SUMMARY

A series of twenty-one incompletely developed pulpless human teeth have been treated conservatively with calcium hydroxide and methylcellulose as a root-filling material. Observation times varied from 14 to 75 months.

Elimination of bacteria was achieved by routine endodontic procedures in conjunction with irrigation and dressing with an aqueous solution of 0.03 per cent chlorhexidine and 0.3 per cent cetrimide.

Of the twenty-one cases, fourteen showed complete, five partial, and two no root development during the period of observation. Periapical repair was complete in twenty of the twenty-one cases and is proceeding satisfactorily in the remaining case. A clinical evaluation of success showed nineteen cases to be successful and two doubtful, with no failures over the period of observation.

Histologic material has been presented which revealed that new tissue had been formed, both apically and within the old canal. This consisted of pulp, interglobular dentine, cementum, and attached periodontal membrane fibers. Two calcified layers of interglobular dentine extended into the old canal and lined it. However, no calcific barrier was present at the coronal extremity of the canal. Thick deposits of cellular and acellular cementum not only covered the newly formed tissue but extended beyond the junction with the old root.

The results of the clinical series and the histologic material support the conservative approach to the treatment of pulpless, incompletely developed teeth. The method is indicated because of its simplicity, the lack of surgical trauma, and the improved prognosis afforded by the further root development.

I wish to express my sincere thanks to Mr. F. R. Henning for reviewing this study, and also to Dr. J. A. Cran, Mrs. L. Zaleski, and Messrs. G. J. Mount, D. Smale, and I. Ozols.

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COMBINED ENDODONTIC-ORTHODONTIC TREATMENT OF TRANSVERSE ROOT FRACTURES IN THE REGION OF THE ALVEOLAR CREST

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Combined endodontic-orthodontic treatment of transverse root fractures in the region of the alveolar crest

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A new method involving the use of combined endodontic-orthodontic treatment to allow treatment of transverse root fractures near the gingival crevice is described, and three case reports illustrating the procedures are presented. The method appears to provide a solution to an otherwise difficult clinical problem.

The treatment of transverse root fractures in which the fracture line lies 1 to 4 mm. below the alveolar crest level has presented clinicians with considerable difficulties, and the prognosis has generally been considered poor.[1-6] The reparative processes which may follow root fracture are (1) healing with calcified tissue, (2) interposition of fibrous connective tissue, or (3) interposition of bone and fibrous connective tissue.[7] An unfavorable response results in the interposition of granulation tissue.

There are several problems in the treatment of transverse root fractures near the alveolar crest if a satisfactory healing response is to be obtained. Bacterial contamination usually occurs because of the proximity of the fracture to the gingival crevice. This contamination may be immediate, or it may follow the regressive changes occasioned by difficulty in immobilization. Immobilization of any fracture is important if calcific union is to be achieved. However, it is extremely difficult, if not impossible, to immobilize permanently most of the

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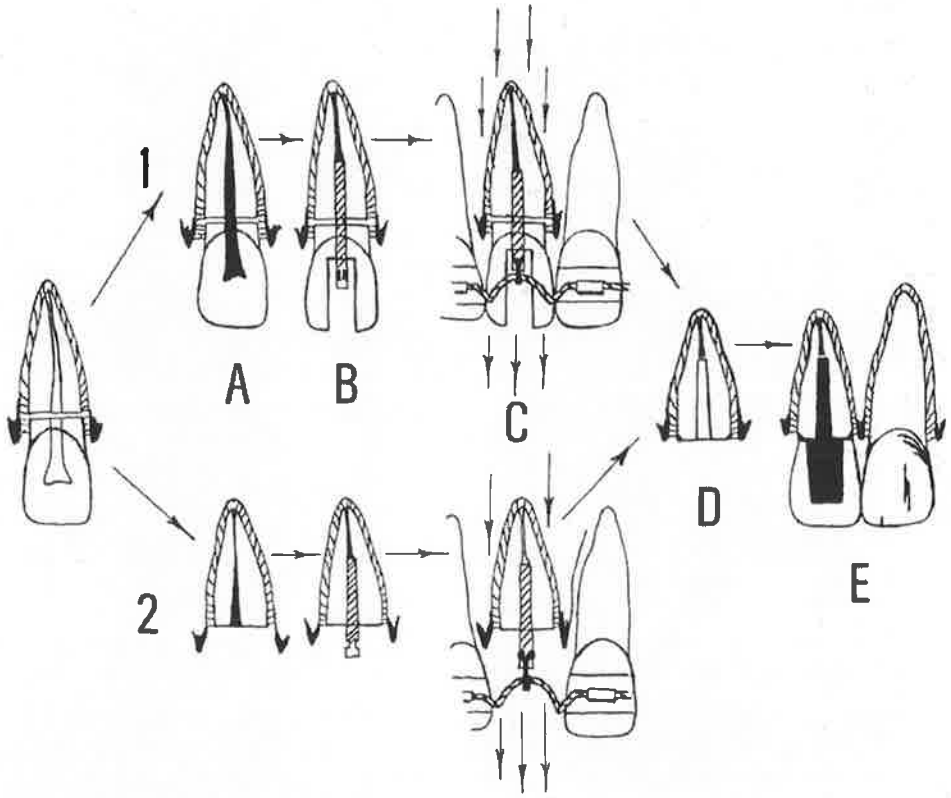


Fig. 1. Diagrammatic representation of the clinical procedures involved in the combined endodontic-orthodontic treatment of transverse root fractures in the region of the alveolar crest. *Method 1: A*, Pulpectomy is carried out through the fracture site and the canal root is filled with gutta-percha and a sealer. *B*, A rectangular segment is removed from the crown, and a post (shank of bur) is inserted through the coronal segment into the apical segment. *C*, Orthodontic bands are applied to adjacent teeth and a spring attached to the post. Controlled orthodontic movement moves the apical segment to a satisfactory vertical position. Incisal and palatal surfaces are ground to allow incisal movement. *D*, Crown and post are removed. *E*. Post retained crown is constructed. *Method 2:* Procedures corresponding to Method 1, except that the coronal segment is removed at the initial stage or after placement of the root filling.

root fractures under consideration. Repair by the interposition of fibrous connective tissue or bone will rarely produce a stable state with these fractures.

If the coronal segment is lost and therapy takes the form of periodontal surgery followed by restorative treatment, many immediate and longer-term problems will probably result. There is difficulty in establishing a stable periodontal state following surgical intervention, because of differing bone and soft-tissue levels. Restorations placed after such extensive surgical procedures usually lie in a position at the base of the gingival crevice, and this is currently considered unfavorable for continuing periodontal health. The restorative problem is also complicated by difficulties in access and control of hemorrhage.

With these problems in mind, it was decided to investigate the possibility of bringing the apical root segment into a favorable relationship with the gingival tissues so that a crown could be constructed satisfactorily. This aim was achieved by combined endodontic and orthodontic treatment.

METHOD

Two methods were evolved, and these are illustrated diagrammatically in Fig. 1. The decision as to which method was to be employed depended on several factors. If the fracture line was below the alveolar crest level and the coronal segment had not suffered gross displacement, then Method 1 was used. In addition, Method 1 was used when the maintenance of esthetics and some functional stimulation during treatment were deemed desirable. Method 2 was generally employed when there had been gross displacement of the coronal segment or the crown had been lost.

The clinical procedures involved in the two methods are as follows:

A. The tooth is treated by vital pulpectomy, followed at the same appointment by the insertion of a root filling of gutta-percha and a sealing agent. In Method 1 the pulpectomy is carried out through the retained crown, while in Method 2 treatment is carried out on the apical segment after removal of the coronal segment.

B. A temporary post is fabricated and cemented, either through the coronal segment into the apical segment (Method 1) or merely into the apical segment (Method 2). The shank of a low-speed bur proved to be one satisfactory form of temporary post. The post must be clear of the occlusion and free to move incisally without interference. If Method 1 is used, the palatal and incisal surfaces are ground out of occlusion. In addition, a rectangular section is removed from the crown to facilitate the attachment of the orthodontic appliance to the post. During the treatment the defect can be covered with a temporary filling material to preserve esthetics.

C. Orthodontic bands are applied to the anterior teeth (and posteriorly if deemed necessary) and a flexible spring is attached to the temporary post. This attachment is facilitated where the head of a bur has been used for this purpose. Activated Twist-Flex wire provides most satisfactory orthodontic movement, requiring minimum adjustments.

D. The tooth is then moved incisally by controlled orthodontic treatment. In Method 1, as the tooth moves, the incisal and palatal surfaces are ground to allow further movement. The extent of the incisal movement is controlled by the relation of the temporary post to the incisal edges of the adjacent teeth. The desired position of the root will be generally attained in 4 weeks. It is advisable to maintain the tooth in passive retention for a period of 6 weeks, thus permitting some stabilization of the periodontal fibers and supporting bone to occur.

The attached gingiva and alveolar bone may be drawn down with the root. Minor periodontal surgery may prove necessary to achieve normal gingival contour.

E. The temporary post and coronal tooth segment are then removed (Method 1), or in Method 2 the post alone is taken out. Preparation for a post-retained crown is now possible, with the margins in a freely accessible position and in correct relationship to the gingival crevice. The crown preparation should have a well-defined cervical bevel to allow

Fig. 2. Case 1. A radiograph of the maxillary right central incisor of a 22-year-old man showing a transverse root fracture 3 to 4 mm. below the alveolar crest level connecting with the gingival crevice at the distal aspect.

Fig. 3. Case 1. Radiograph showing the completed root filling following a vital pulpectomy (Method 1A).

marginal splinting and thus reduce the possibility of future vertical root fracture.

F. After insertion of the crown, an orthodontic retention plate should be constructed. This should be worn for a period of 6 months to allow for further stabilization of the periodontal fibers.

CASE REPORTS

CASE 1

A 22-year-old man, who had suffered a blow to the maxillary right central incisor from a billiard ball, was seen 24 hours after his injury. Examination disclosed a transverse fracture approximately 3 mm. from the alveolar crest. The fracture line connected with the gingival crevice at the distal margin. There was moderate mobility of the tooth. Treatment as described in Method 1 was carried out and is illustrated in Figs. 2 to 9. The tooth was moved incisally a distance of 4 mm. over a period of 6 weeks and was then held in position for an additional 6 weeks. The residual root length was 13 mm. Periodontal surgery proved to be necessary because the attached gingiva and alveolar crest accompanied the root in its incisal movement. (An examination of Fig. 7 shows the slanting of the interdental crest of the alveolar bone.) The tooth was restored with a post-retained, procelain-bonded-to-gold crown, which incorporated a gold bevel at the cervical margin to ensure marginal splinting (Figs. 8 and 9). An orthodontic retention plate was then inserted and maintained in position for 6 months.

CASE 2

A 9-year-old girl received a blow to the maxillary right central incisor while playing at school. She was referred for treatment 2 months after the accident, when an examination showed that a transverse root fracture was present in a position 2 to 3 mm. below the

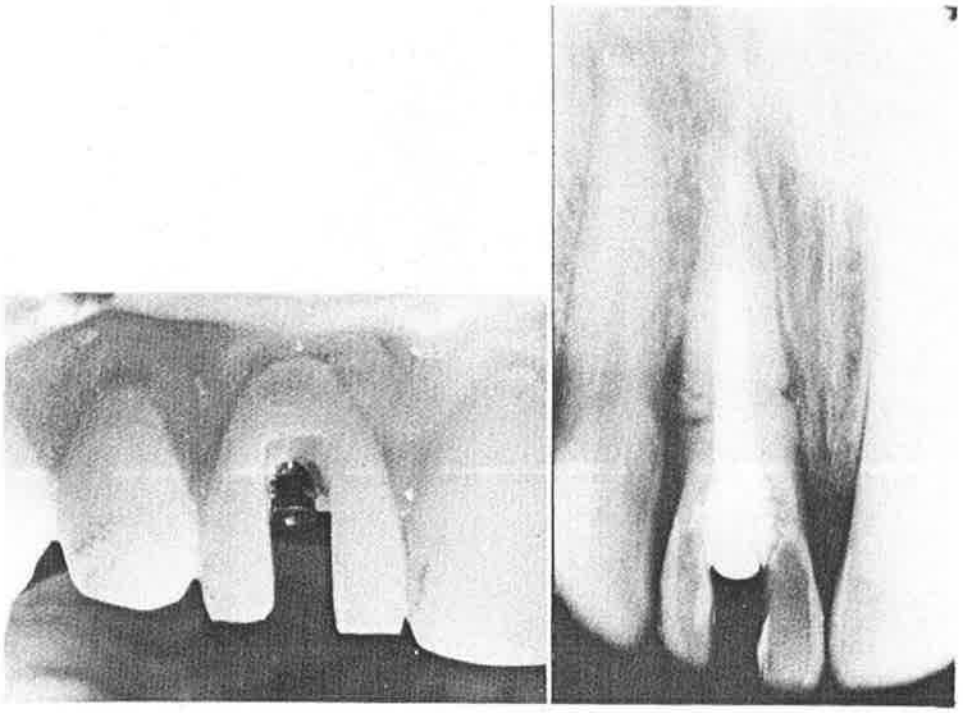


Fig. 4

Fig. 5

Fig. 4. Case 1. The shank of the bur, inserted through the coronal segment into the apical fragment, is seen through the rectangular section removed from the crown. The incisal and palatal surfaces have been ground (Method 1B).

Fig. 5. Case 1. Radiograph showing the bur shank in position.

alveolar crest level (Fig. 10). There was evidence of marginal bone resorption, and the coronal segment was mobile. As there was obvious displacement of the two segments and bacterial contamination via the gingival crevice, treatment as described in Method 2 was carried out (Figs. 11 to 15). Orthodontic treatment moved the apical segment 3 mm. incisally in a period of 4 weeks. A simple activated spring was used to effect movement of this root (Figs. 12 and 13). The root was retained in that position for 6 weeks before crowning. The residual root length was 13.5 mm. (Fig. 14). The post-retained crown was constructed of porcelain bonded to gold (Fig. 15).

CASE 3

A 19-year-old male patient received a blow to the maxillary right central incisor which already had a root filling and crown. Because of the poor nature of the crown and the direction of the blow, an oblique fracture of the root resulted (Fig. 16). Treatment described in Method 2 was carried out (Figs. 17 to 22). Periodontal correction was necessary as the attached gingiva and alveolar bone followed the root in its cervical movement. The residual root length was 14 mm. A porcelain-bonded-to-gold crown incorporating marginal splinting was then inserted (Fig. 21).

DISCUSSION

It has been customary in the treatment of transverse fractures in the region of the alveolar crest to attempt retention of the coronal segment by splinting the fractured segments, using various methods. The object of treatment is to obtain, if possible, a calcific union between the fractured segments. Calcific union between the fracture sites is a remote possibility, and generally the coronal segment will be lost because of progressive resorption of marginal bone and interposition of granulation tissue. Success of intracanal splinting[8]

Fig. 6. Case 1. Two months after the initiation of treatment, the tooth has been moved downward a distance of 4 mm. and is shown in retention. Note that the attached gingiva has been drawn down with the tooth in its incisal movement.

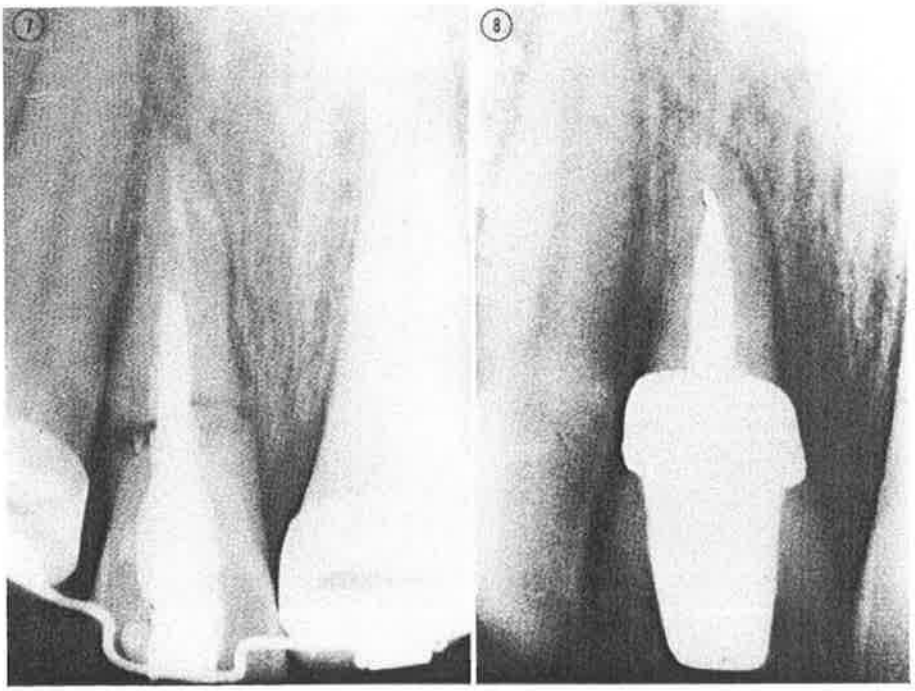


Fig. 7. Case 1. Radiograph showing the tooth after it had been moved 4 mm. by controlled orthodontic treatment. Note the slanting of alveolar bone which has accompanied the tooth in its incisal movement (Method 1C).

Fig. 8. Case 1. Radiograph showing the completed crown in position. Note the marked cervical gold bevel of the crown incorporated to avoid future root fracture. A 1:1 crown-root ratio has been achieved.

or endodontic implants[9, 10] is dependent on the integrity of the gingival crevice in relation to the fracture site. Where such integrity has been destroyed, or is likely to be lost during the patient's lifetime, the prognosis is poor. Periodontal surgery[11, 12] has been used to provide access to the apical segments of teeth with transverse fractures in the region of the alveolar crest, but generally, as this surgery involves the removal of alveolar bone, there may be damage to the supporting tissues of the neighboring teeth and the esthetic result may be poor. In addition, maintenance of the gingival tissues on the palatal aspect of such

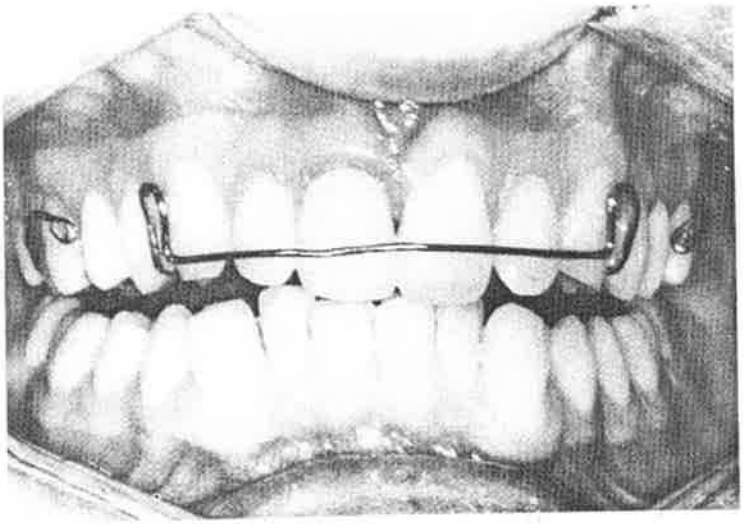


Fig. 9. Case 1. The crown at the time of its insertion. An orthodontic retention plate is in position.

Fig. 10. Case 2. Radiograph of the maxillary right central incisor of a 9-year-old girl showing a transverse root fracture 2 to 3 mm. below the alveolar crest level. Marginal bone resorption is evident in relation to the fracture site.

Fig. 11. Case 2. Radiograph showing the post in position after the tooth had been root filled with gutta-percha and sealer (Method 2B).

traumatized maxillary incisors is often difficult. Andreason[1] has concluded that "When the fracture line is located close to the gingival crevice, the prognosis is poor and extraction is usually mandatory." Therefore, the major difficulties in treatment of transverse root fractures near the alveolar crest are immobilization, the avoidance of bacterial invasion via the gingival crevice, and, if the coronal segment is lost, placement of a satisfactory restoration and establishment of periodontal health.

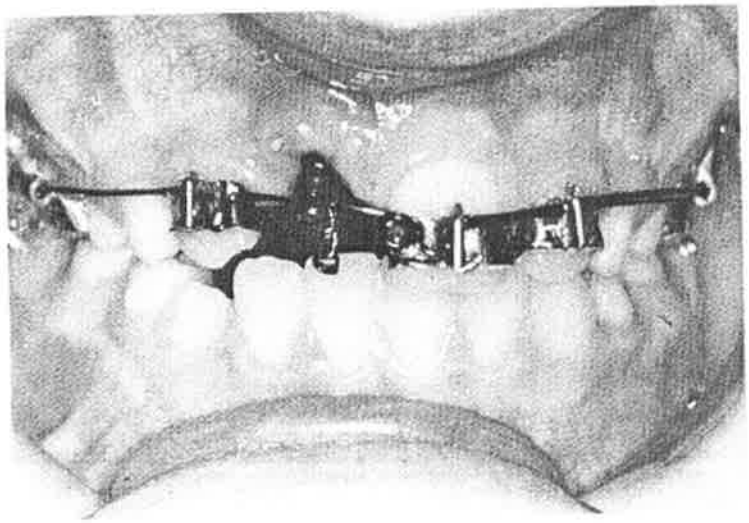


Fig. 12. Case 2. Orthodontic bands are shown in position. The apical segment was being moved incisally by means of a simple spring attached to the post (Method 2C).

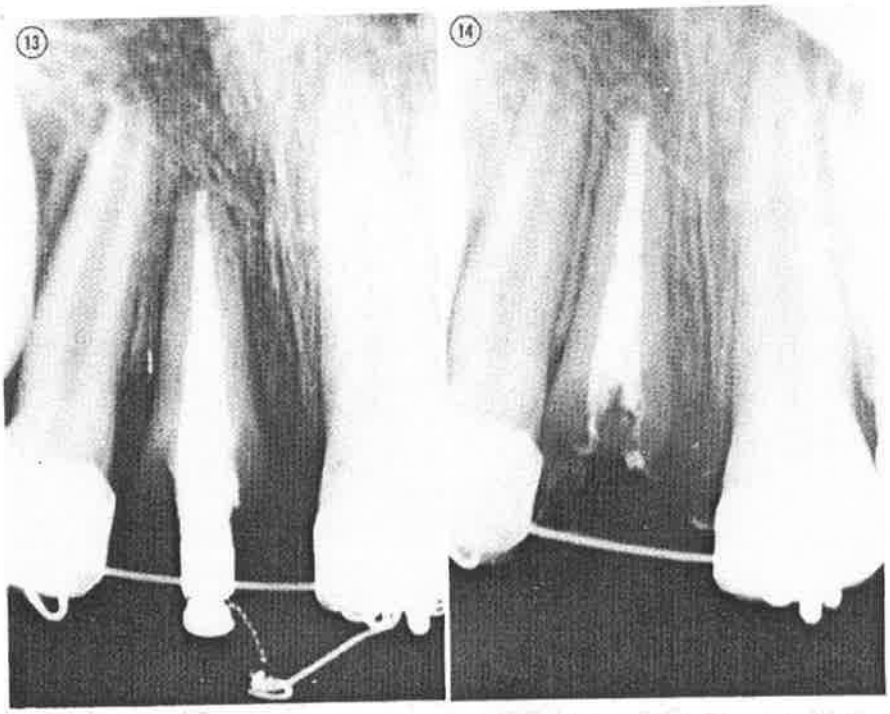


Fig. 13. Case 2. Radiograph showing the root after it had been moved incisally a distance of 3 mm.

Fig. 14. Case 2. Radiograph after removal of the post (Method 2D). The residual root length was 13.5 mm., which permitted a 1:1 crown-root ratio. There is radiographic evidence of bone repair in the previously resorbed cervical area. (Refer to Fig. 11.)

Of the two methods just described, the first, in which the crown of the tooth is retained until the apical segment is in the correct position, proved to have advantages in that the endodontic procedures could be carried out more satisfactorily under rubber dam without hemorrhagic problems. In addition, esthetics could be maintained during treatment. However, the orthodontic treatment is more difficult than in Method 2, where simple and direct access to the post can be readily achieved.

Fig. 15. **Case 2. Eighteen months after the insertion of a post-retained, procelain-fused-to-gold crown.**

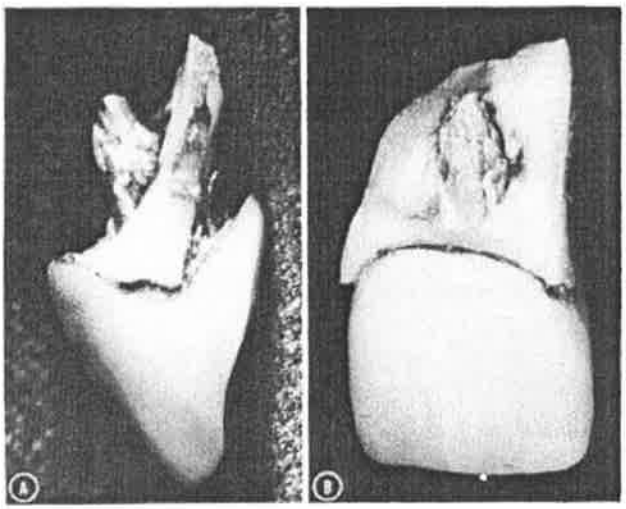


Fig. 16. **Case 3. The dislodged crown of the maxillary right central incisor with the obliquely fractured root fragment in position.**

It is important when assessing teeth for this treatment to ensure that the residual root length will provide a crown-root ratio of at least 1:1. In most instances this means that the apical root segment must have a length of 12 to 15 mm.

Relapse in the form of ingression of the root has not been observed in the cases which have been treated, the longest follow-up period having been 18 months.

In addition to the obvious functional advantages, the economics of the present procedure would compare more than favorably with extraction of the tooth and provision of an anterior bridge.

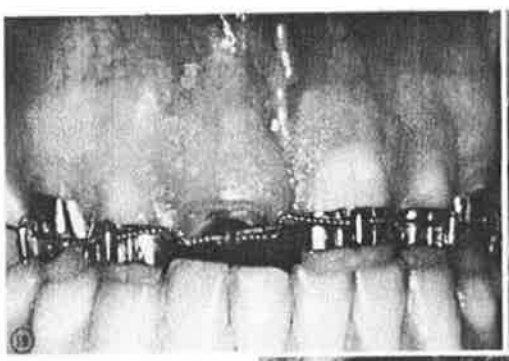
The application of endodontic-orthodontic treatment need not be confined to transverse root fractures. Elevation of the root may be of use in several other pathologic situations. Oblique crown-root fractures often occur following traumatic or sporting accidents, where generally the fracture line extends deeply on the palatal aspect. It is often extremely difficult to establish a satisfactory palatal margin during crown preparation and, unless local gingivectomy and osteotomy are carried out, periodontal complications are a likely long-term

Fig. 17

Fig. 18

Fig. 17. Case 3. Clinical appearance after insertion of the post (shank of bur) into the apical segment of the root.

Fig. 18. Case 3. Radiograph of apical segment after it had been moved incisally 4 mm. Note the Twist-Flex wire in position.



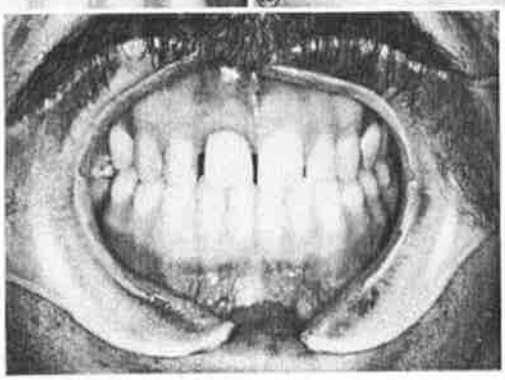


Fig. 19. Case 3. Clinical appearance at the completion of orthodontic movement. The attached gingiva has accompanied the apical segment in its incisal movement as shown by the differing gingival levels. Twist-flex wire is in a passive position.

Fig. 20. Case 3. Periodontal tissues are shown to be healing satisfactorily after the removal of packs following minor periodontal contouring. Note the twist-flex wire still attached to the post.

Fig. 21. Case 3. Porcelain-fused-to-gold, post-retained crown at the time of its insertion. There is a slight display of gold at the gingival margin due to the necessity for cervical splinting.

Fig. 22. Case 3. Radiograph showing the crown in position at the time of insertion.

result. Even if periodontal contouring is carried out, a palatal defect may still result because of inconsistent bone levels. Elevation of the root to allow access to the palatal margin will overcome these problems. Case 3 has illustrated this application of the present method. Teeth with root perforations, caries, or resorption in a position close to the gingival crevice may also be treated to advantage by this method. The perforated, carious, or resorbed area could be elevated to such a position that it could be eliminated and a new crown constructed on a sound root with normal supporting bone.

It can be concluded that combined endodontic-orthodontic therapy in treatment of root fractures offers a solution to a difficult clinical problem. Crown construction on accessible margins is achieved without extensive surgery and should provide a sound basis for future periodontal health and stability of the tooth.

SUMMARY

A new method involving the use of combined endodontic-orthodontic treatment to allow treatment of transverse root fractures near the gingival crevice has been described, and three case reports illustrating the procedures have been presented.

The method appears to provide a solution to an otherwise difficult clinical problem.

The author wishes to express his sincere thanks to Drs. F. R. Henning and G. J. Mount, who have reviewed the paper, Miss Katie Gregson, Mrs. L. Zaleski, and Mr. T. Rollings for technical assistance, and to the participating clinicians—John Bloomfield, Nigel Clarke, Lester Duthy, Iain Edwards, John Kirkwood, Grahame Moore, and Bruce Wark—who carried out the orthodontic, periodontic, and crown therapy.

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A CLINICAL EVALUATION OF ROOT EXTRUSION

Geoffrey S Heithersay

A diagrammatic summary of the clinical results following root extrusion in 57 teeth is shown in Tables 1–8

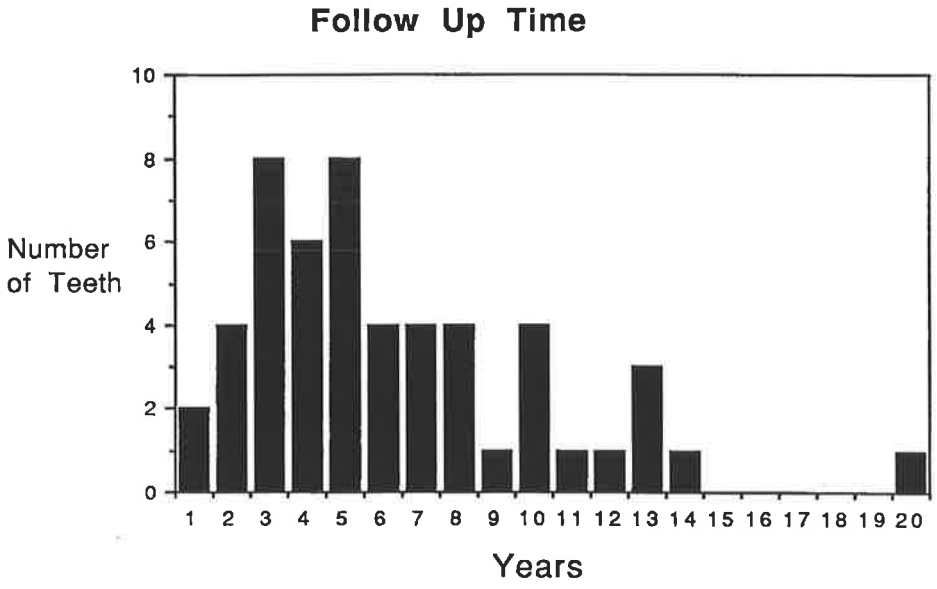

Table 2: Distribution of extruded teeth.

Reason for Extrusion

Subgingival	Fracture = 48 Resorption = 7 Perforation = 1 Caries = 1

Table 3: The reason for extrusion.

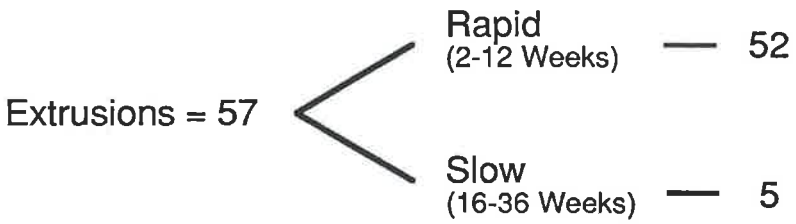

Table 4: Number of teeth extruded by rapid or slow method.

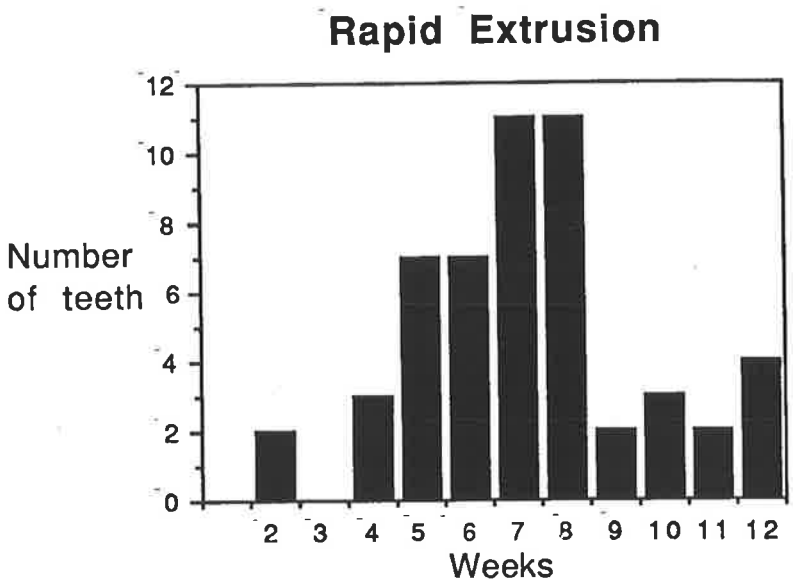

Table 5: Shows the distribution of treatment times.

Resorption

Rapid Extrusion (52)	
	Apical Resorption (0)
	Repaired Surface Resorption (3)
Slow Extrusion (5)	
	Apical Resorption (1)
	Repaired Surface Resorption (1)

Table 6: Indicates resorption in slow or rapidly extruded teeth.

Extrusion

Cause of Failure

Additional Undiagnosed Root Fracture = 1 Root Fracture of Crowned Tooth = 3 New Trauma = 1

Table 7: Causes of failure

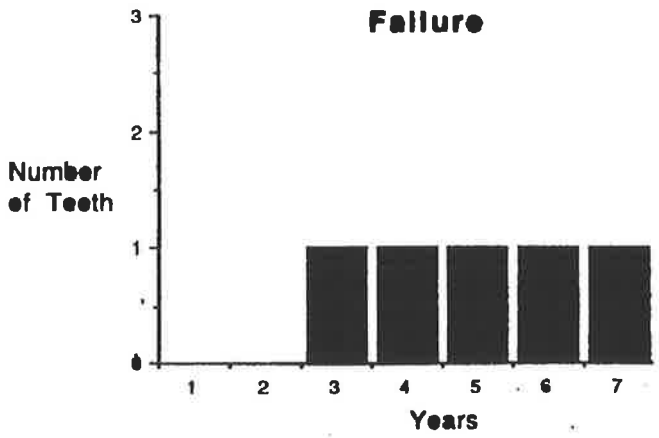

Table 8: The survival time for teeth which have failed.

APPENDIX 3

Contents

Release and diffusion through human tooth roots *in vitro* of corticosteroid and tetracycline trace molecules from Ledermix® paste

Abbott PV, Heithersay GS, Hume WR. Release and diffusion through human tooth roots *in vitro* of corticosteroid and tetracycline trace molecules from Ledermix® paste. Endod Dent Traumatol 1988; 4: 55–62.

Abstract – The release of corticosteroid and antibiotic tracer molecules in Ledermix® paste from the pulp space to the external environment of human tooth roots was determined *in vitro*. For demeclocycline little of the tracer was released through the root apex; the great majority diffused through dentine. For triamcinolone about one-third of the tracer left the roots via the apical foramen; the remainder exited via the dentine. The rate of release of the tracers was highest during the first day, and declined exponentially with time thereafter. After 14 weeks, 98% of triamcinolone and 66% of demeclocycline had been released. In the teeth examined, diffusion rate was not related to the age or sex of the donor. Total release of the tracers was directly related to the area of contact between the paste and dentine. The data obtained are of immediate clinical relevance, and also add to our general understanding of drug dynamics in tooth roots.

Paul Vincent Abbott, Geoffrey Sinclair Heithersay and Wyatt Roderic Hume

School of Dentistry, University of Adelaide, Adelaide, Australia

Key words: endodontics, diffusion, therapeutics, triamcinolone, demeclocycline.

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Accepted for publication 19 October 1987.

Barriers to diffusion of Ledermix® paste in radicular dentine

Abbott PV, Hume WR, Heithersay GS. Barriers to diffusion of Ledermix® paste in radicular dentine. Endod Dent Traumatol 1989; 5: 98–101.

Abstract – Freshly extracted human single-rooted teeth with a single root canal were used to study the effects of 2 irrigation regimens and the effect of cementum on the diffusion of corticosteroid and antibiotic tracer molecules from Ledermix® paste placed in the pulp space. An irrigation regime that combined the use of 15% EDTAC and 1% NaOCl resulted in a significant increase in the permeation of the trace molecules through dentine compared with teeth that were irrigated with Savlon® solution. Mechanical removal of the cementum also resulted in a significant increase in the permeation of the trace molecules. This study demonstrated that neither the smear layer nor the cementum were complete barriers to diffusion. The data obtained appeared to be of clinical relevance and provided further understanding of the dynamics of drugs in tooth roots.

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Key words: endodontics; diffusion; therapeutics; triamcinolone; demeclocycline; root canal medicaments; irrigation.

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Accepted for publication November 8, 1988.

The release and diffusion through human coronal dentine *in vitro* of triamcinolone and demeclocycline from Ledermix® paste

Abbott PV, Hume WR, Heithersay GS. The release and diffusion through human coronal dentine *in vitro* of triamcinolone and demeclocycline from Ledermix® paste. Endod Dent Traumatol 1989; 5:92–97.

Abstract – Crowns from freshly extracted human third molar teeth were used to quantify the release and diffusion of corticosteroid and antibiotic tracer molecules from Ledermix® paste used as an indirect pulp-capping agent. These molecules readily diffused through dentine and reached a peak rate of diffusion at 2 h. The rate then decreased exponentially with time. The concentrations of the drugs in the dentine were calculated; this showed that a gradient existed from the cavity floor to the pulp space. The data obtained appeared to have clinical relevance and helped explain the therapeutic benefits of this medicament when used as an indirect pulp-capping agent.

Paul Vincent Abbott, Wyatt Roderic Hume, Geoffrey Sinclair Heithersay

School of Dentistry, University of Adelaide, Adelaide, Australia

Key words: pulp; diffusion; therapeutics; triamcinolone; demeclocycline.

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Accepted for publication November 8, 1988.

Evidence for direct inhibition of dentinoclasts by a corticosteroid/antibiotic endodontic paste

Pierce A, Heithersay G, Lindskog S. Evidence for direct inhibition of dentinoclasts by a corticosteroid/antibiotic endodontic paste. Endod Dent Traumatol 1988; 4: 44–45.

Abstract – A previous report demonstrated that intrapulpal application of an antibiotic/corticosteroid combination effectively eliminates experimentally induced external inflammatory resorption in monkey teeth. The aim of this study was to examine the direct effects of this medicament on dentinoclasts cultured *in vitro*. Isolated dentinoclasts were cultured in the presence of either the endodontic paste or antibiotics. Results showed that the steroid component of the paste directly inhibited the spreading of dentinoclasts, suggesting that this medicament acts by detaching resorbing dentinoclasts from the root surface.

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Key words: antibiotic, cell culture, corticosteroid, dentin, resorption.

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Accepted for publication 9 July 1987.

Effects of combining Ledermix® and calcium hydroxide pastes on the diffusion of corticosteroid and tetracycline through human tooth roots *in vitro*

Abbott PV, Hume WR, Heithersay GS. Effects of combining Ledermix® and calcium hydroxide pastes on the diffusion of corticosteroid and tetracycline through human tooth roots *in vitro*. Endod Dent Traumatol 1989; 5: 188–192.

Abstract – A 50:50 mixture of a corticosteroid/antibiotic paste and calcium hydroxide has been used clinically as a root canal dressing agent. This study investigated the effect on the release and diffusion of the corticosteroid and antibiotic components of Ledermix® paste when it was mixed with a calcium hydroxide–methyl cellulose paste. The release rates of the trace molecules were lower when the mixture was used compared with release from Ledermix alone. The results indicated that this combination of materials, when used a long-term intracanal dressing, was likely to be more effective than Ledermix alone.

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Key words: endodontics; diffusion; therapeutics; triamcinolone; demeclocycline; calcium hydroxide.

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Accepted for publication January 21, 1989.

Some effects of Ledermix® paste and Pulpdent® paste on mouse fibroblasts and on bacteria *in vitro*

Taylor MA, Hume WR, Heithersay GS. Some effects of Ledermix® paste and Pulpdent® paste on mouse fibroblasts and on bacteria *in vitro*. Endod Dent Traumatol 1989; 5: 266–273.

Abstract – Dilutions of Ledermix® paste, Pulpdent® paste and a mixture of equal parts by weight of Ledermix paste and Pulpdent paste were added to *in vitro* cultures of mouse fibroblasts or bacteria for 24 h, and various cell functions were then examined: mitosis in and survival of fibroblasts, and survival of *Lactobacillus casei* or *Streptococcus mutans*. Ledermix was found to reversibly inhibit mitosis while present in the concentrations range 10^{-3} to 10^{-6} mg/ml. Mixing with Pulpdent did not modify this antimitotic effect. Ledermix killed mouse fibroblasts at 10^{-3} mg/ml and above, while Pulpdent killed at 1 mg/ml and above. The toxic effect of Ledermix was slightly inhibited by mixing it with Pulpdent. Ledermix killed *S. mutans* at about the same concentration at which it killed the mammalian cells, but required a one thousand-fold greater concentration to kill *L. casei*. Pulpdent killed both *L. casei* and *S. mutans* at approximately one-fifth of the concentration at which it killed the mammalian cells. Pulpdent slightly potentiated the antibacterial effect of Ledermix. The pH of Pulpdent was reduced by approximately 0.3 units by mixing with Ledermix. The present data showed that the 50:50 mix of Ledermix and Pulpdent retained the properties examined that are thought to be of therapeutic benefit, while not increasing the toxicity of the component parts to mammalian cells.

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Key words: fibroblasts; cellular effects; bacteria.

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Therapeutic delivery of calcitonin to inhibit external inflammatory root resorption

I. Diffusion kinetics of calcitonin through the dental root

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Wiebkin OW, Cardaci SC, Heithersay GS, Pierce AM. Therapeutic delivery of calcitonin to inhibit external inflammatory root resorption. I. Diffusion kinetics of calcitonin through the dental root. Endod Dent Traumatol 1996; 12: 265–271. © Munksgaard, 1996.

Abstract – Insertion of calcitonin into root canals of monkey teeth has been shown to inhibit external inflammatory root resorption and suppress inflammation. Regulation of this therapeutic event depends upon the rate of arrival (diffusion) of the hormone at sites of resorptive activity. In the present study, the diffusion characteristics of calcitonin through the dental root in an extracted human-tooth model are described, and the role of cementum in the diffusion process is also addressed. Root-canals were endodontically prepared to form a reservoir for [^{125}I]-calcitonin, and macerated to remove organic material from dentinal tubules. In teeth with intact cementum, an initial period of delay (4-5h) prior to the detection of calcitonin at the external tooth-root surface was followed by a rapid release of the calcitonin during the first 10.5h (rate peaks at 6h). Slower, sustained releases of calcitonin through intact cementum were measured for the following 9 days. Removal of cementum, to expose "smear-free" dentine, resulted in an earlier efflux of calcitonin (2h) at external tooth surfaces and increased amounts of calcitonin release over 9 days. Biphasic delivery of calcitonin by such internal diffusion mechanisms suggests that loss of cementum will enhance therapeutic availability, while prolonged delivery to intact external dental-root surfaces following early intra-canal placement may also be useful for the therapeutic prevention of external inflammatory root resorption.

Key words: calcitonin; cementum; dentine; inflammatory root resorption; odontoclasts
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Accepted February 20, 1996

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Therapeutic delivery of calcitonin to inhibit external inflammatory root resorption

II. Influence of calcitonin binding to root mineral

Wiebkin OW, Cardaci SC, Heithersay GS, Pierce AM. Therapeutic delivery of calcitonin to inhibit external inflammatory root resorption. II. Influence of calcitonin binding to root mineral. Endod Dent Traumatol 1996; 12: 272–276. © Munksgaard, 1996.

Abstract – Experimentally-induced external inflammatory tooth-root resorption can be inhibited by therapeutic doses of calcitonin. Such doses can be delivered by an intrinsically slow diffusion pathway, from a reservoir in endodontically-debrided root canals, via the dentinal tubules. While the kinetics of this journey have been followed in an earlier report, the binding characteristics of calcitonin to the tooth mineral, which will be responsible, in part, for these kinetics, have not been reported before. The current study examines the binding potential of calcitonin to root mineral and addresses the potential role of non-specific binding proteins. A modified Scatchard plot indicated that a simple non-reactive type of ligand binding exists between calcitonin and root mineral, represented by a small number of identical binding sites. This interaction is both strong and reversible. Furthermore, it appears to be time-dependent with more time being required for the residual ligands to interact with the diminishing numbers of free calcitonin-binding sites. While preloaded [^{125}I]-calcitonin could be incompletely (75-91%) displaced from dental-root material by non-radioactive calcitonin, its release was slow over 23h. Calcitonin was four times as effective as bovine-serum albumin in competing for common "calcitonin binding sites" on macerated dental-root material. Thus, even in the presence of extraneous protein, calcitonin will bind tightly but reversibly to tooth-root material, making it a good candidate for therapeutically protracted delivery to external root surfaces from root canals.

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Key words: calcitonin; dentine; inflammatory root resorption; mineral; odontoclasts

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Accepted February 29, 1996

International Endodontic Journal (1991) 24, 308–316

An SEM study of the effects of different irrigation sequences and ultrasonics

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Summary. The root canals of 30 extracted human teeth with single canals were prepared biomechanically with hand instruments using a flaring technique. Three different irrigation regimes were used, with and without ultrasonic activation of a root canal file. The six irrigation sequences used in this study were as follows: Savlon, Savlon with ultrasound, EDTAC/NaOCl/EDTAC, EDTAC/NaOCl/EDTAC with ultrasound, NaOCl/EDTAC/NaOCl, and NaOCl/EDTAC/NaOCl with ultrasound. Scanning electron microscopic (SEM) examination of the prepared root canal walls showed a complete smear layer when Savlon was used. Ultrasound reduced the amount of smear with Savlon, but did not do so significantly with the other irrigation regimes. The most effective irrigation regime for removing smear layer and other debris was EDTAC/NaOCl/EDTAC. In all groups there was a significant decrease in cleaning efficiency as the apical end of the canal was approached.

International Endodontic Journal (1992), 25, 199–204

Tissue responses to Hydron, assessed by intramuscular implantation

R. J. REID, D. F. WILSON, K. K. CHAU, G. S. HEITHERSAY & P. S. HEIJKOOP
Department of Dentistry, The University of Adelaide, Adelaide, South Australia

Summary

Freshly mixed polymerized Hydron root canal filling material, fully set AH26 and Teflon were implanted in the quadriceps muscle of guinea pigs and assessed histologically at 2 days, 1, 2, 3, 12 and 26 weeks after implantation. All materials were characterized by peri-implant fibrous connective tissue capsule formation. Von Kossa-positive calcific material was observed at the implant-tissue interface of Hydron implants. The amount of apparently calcified material increased with time. Inflammation was not a prominent tissue response for any of the test materials, nor was a foreign body giant cell response.

Keywords: **biocompatibility testing, endodontics, Hydron, Poly-HEMA, root-filling materials.**

International Endodontic J 1992 25, 192-198

Tissue responses to Hydron, assessed by intraosseous implantation

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Summary

Teflon tubes containing freshly mixed, polymerized Hydron root canal filling material, fully set AH26 or Teflon were implanted into the mandible of guinea pigs and assessed histologically at 2 days, 1, 2, 4, 12 and 26 weeks. None of the materials tested elicited signs of overt or significant tissue damage, and polymerized Hydron was assessed to be as biocompatible as fully set AH26 and Teflon. Bone formed in very close apposition to the polymerized Hydron, whereas a soft tissue capsule separated the regenerated bone from implants of AH26 and Teflon.

Keywords: biocompatibility testing, endodontics, Hydron, Poly-HEMA, root-filling materials.

International Endodontic Journal (1992) 25, 205–212

Cell responses to Hydron by a new *in-vitro* method

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Summary

An *in-vitro* biotoxicity test system, suitable for the assessment of endodontic filling materials, has been developed and used to test cell responses to Hydron, AH26 and Tubliseal. A robust, well-characterized and stable cell line (L-cells) which was grown as uniform cultures on Millipore filters, has been used as indicator cells. As they approached confluence they were exposed to test substances for 24 h and biosynthetic activities were measured. The test system is a modification of that described by Wennberg *et al.* (1979). By inverting the cultures on organ-culture rafts, cells were separated from the test material, which was placed on top of the Millipore filters. Freshly mixed polymerizing Hydron and prepolymerized Hydron were tested. The cell responses were compared with those of cultures exposed to freshly mixed AH26 and Tubliseal. Polymerizing and prepolymerized Hydron depressed both cell division, assessed by ^{3}H-thymidine incorporation, and the synthesis and secretion of matrix material as measured by precipitable ^{35}S-sulphate. Prepolymerized Hydron decreased cell functions by 59% and 56% of live cell controls, respectively, while the freshly mixed polymerizing Hydron inhibited biosynthesis by 89% and 94%, respectively. The data for polymerizing Hydron were compared with results for other root-filling materials and showed similar values to those for Tubliseal (92% and 95%), but greater inhibition of biosynthesis than for AH26 (53% and 50%). The AH26 values were similar to those obtained from cultures exposed to the prepolymerized Hydron. Recovery of biosynthetic capacity by these cultures after removal of all endodontic material was also assessed. Partial biosynthetic recovery of cell cultures was observed 24 h after removal of prepolymerized Hydron. The unpolymerized Hydron continued to yield a soluble component which substantially depressed biosynthetic activity of the experimental cultures up to 14 days. In general, the results indicated that Hydron, particularly in its freshly mixed state, when not in actual cell contact, depressed cell division and extracellular-matrix synthesis. Data derived from similar *in-vitro* testing with AH26 and Tubliseal revealed that they both inhibited cell division and matrix synthesis. Tubliseal inhibited these cell responses to the same extent as polymerizing Hydron. Polymerizing Hydron was significantly more toxic than AH26, while there were no significant differences in the levels of toxicity of polymerized Hydron and AH26.

Keywords: extracellular matrix metabolism, Hydron, *in-vitro* biotoxicity, Poly-HEMA, root-filling materials.

International Endodontic Journal (1992) 25, 213–220

A five-year study of Hydron root canal fillings

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The University of Adelaide, School of Dentistry, Adelaide, South Australia

Summary

A prospective clinical and radiographic study was conducted in order to compare Hydron and laterally condensed gutta-percha/AH-26 root canal fillings. Paralleling technique periapical radiographs were taken preoperatively, postoperatively and at recall appointments at post-treatment intervals of 6 months, 1 year, 2 years, 3 years and 5 years. Clinical examination at the recall appointments revealed no adverse signs or symptoms amongst all the patients who attended (mean attendance 44.5% at each interval). Radiographs were scored according to the periapical status of the treated root, and comparable bone healing rates were observed between the two root-filling materials. Among the patients attending recall appointments, there were no radiographic signs of failure of any of the 39 gutta-percha/AH-26 root canal fillings. However, three of the 35 canals filled with Hydron were classified as failures, and four required further assessment after the 5-year recall appointment. This study indicated that Hydron and gutta-percha/AH-26 root canal fillings were well accepted but, on the basis of radiographic assessment, success with gutta-percha/AH-26 was more predictable.

Keywords: AH-26, endodontics, Hydron, Poly-HEMA, root-filling materials.

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Tooth discoloration by blood: an *in vitro* histochemical study

Marin PD, Bartold PM, Heithersay GS. Tooth discoloration by blood: an *in vitro* histochemical study. Endod Dent Traumatol 1997; 13: 132–138. © Munksgaard, 1997.

Abstract – An *in vitro* model, using a modification of a technique devised by Freccia & Peters, was developed to investigate tooth staining following pulpal haemorrhage. Samples of whole blood, erythrocytes, plasma and platelet concentrate and saline were individually placed in the pulp chambers of groups of five teeth and centrifuged twice daily for 25 min over a period of 3 consecutive days. This confirmed that the blood pigment responsible for the staining was found only in those samples containing erythrocytes. Teeth stained with packed red cells were then prepared for histological examination and subjected to four histochemical tests: (1) benzidine, (2) zinc leuco, (3) Perl's and (4) Turnbull Blue to analyse some of the biochemical changes following haemorrhage into the pulp chamber. These tests showed that, following haemolysis of erythrocytes within dentine, haemoglobin was found either intact or as one of the haematin molecules with no further breakdown of the haem structure and no evidence of any free ferric ions or haemosiderin.

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Key words: blood pigments; catabolism of haemoglobin; histochemical tests

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Hydroxyl radical activity in thermo-catalytically bleached root-filled teeth

Dahlstrom SW, Heithersay GS, Bridges TE. Hydroxyl radical activity in thermo-catalytically bleached root-filled teeth. Endod Dent Traumatol 1997; 13: 119–125. © Munksgaard, 1997.

Abstract – Intra-coronal bleaching of root-filled teeth has been associated with invasive cervical root resorption. It is considered that during bleaching hydrogen peroxide diffuses through the tooth structure into the cervical periodontium, resulting in periodontal tissue destruction and initiating a resorptive process. Hydrogen peroxide is capable of generating hydroxyl radical, an oxygen-derived free radical, in the presence of ferrous salts. Hydroxyl radicals are extremely reactive and have been shown to degrade components of connective tissue, particularly collagen and hyaluronic acid. The aim of the present study was to determine whether hydroxyl radicals are generated during the bleaching of root-filled teeth which have been discoloured by blood. Forty extracted human premolar teeth were root-filled with gutta-percha and AH26 sealer cement. Twenty of the teeth were experimentally discoloured by blood. All teeth were then thermo-catalytically bleached using 30% hydrogen peroxide while tooth roots were seated in a test solution of sodium salicylate. Hydroxyl radical generation was determined by the detection of reaction products of this radical with salicylate using high performance liquid chromatography with electrochemical detection (HPLC-ECD). The presence of hydroxyl radicals was detected in twenty-five of the teeth. There was a significant association between the production of hydroxyl radicals and the presence of tooth discolouration caused by blood components. Greatest yields of hydroxyl radicals occurred in teeth in which EDTA had been used to clean the pulp chamber prior to bleaching. It was concluded that hydroxyl radicals are generated during the thermo-catalytic bleaching of root-filled teeth. Generation of this toxic chemical species may be one mechanism underlying periodontal tissue destruction and root resorption after intra-coronal bleaching.

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Key words: cervical root resorption; free radical production; hydrogen peroxide; intra-coronal bleaching; tooth discolouration

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A quantitative comparison of traditional and non-peroxide bleaching agents

Marin PD, Heithersay GS, Bridges TE. A quantitative comparison of traditional and non-peroxide bleaching agents. Endod Dent Traumatol 1998; 14: 64–67. © Munksgaard, 1998.

Abstract Single-rooted premolar teeth, stained with blood utilizing the technique devised by Freccia & Peters (1981), were subjected to traditional and non-peroxide bleaching agents. Colour changes were recorded over a period of 7 days using a Speedmaster R75-CP Reflection Densitometer. The most efficient removal of staining occurred after the application of 30% hydrogen peroxide, with sodium perborate being 75% as effective. All bleaching agents realized their optimum efficacy within the first 3 days. A combination of three enzymes (amylase, lipase and trypsin) with disodium edetate was not as effective as the routine bleaching agents; however, the combination did have a modifying effect on the blood stains. It is suggested that other non-peroxide agents should be investigated to determine their efficacy in removing staining from experimentally induced blood-stained teeth.

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Key words: bleaching agents; hydrogen peroxide; sodium perborate

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J Dent Res April 1990 *Vol. 69 No. 4* *Australian and New Zealand Division*

17 HEIJKOOP F.S.,* HEITHERSAY G.S., MAKINSON O.F. Dental and Industrial Materials as Temporary Endodontic Access Seals. Univ of Adelaide, Adelaide, South Australia.

The ability of several dental and industrial materials to seal endodontic access cavities prepared in vitro was assessed. The dimensional stability and wear resistance of those materials found to seal adequately was also assessed. Materials tested were Cavit, Genesis, Impregum F, IRM encapsulated, Ketac-Bond encapsulated, Permadyne, Ramitec, TERM, 5 minute Araldite with Al_2O_3 400 grit in a ratio of 1:2, E-POX-E putty, and 10 minute E-POX-E putty. Premolars were endodontically prepared to size 30 with a regime of EDTA and NaOCl and dried prior to sealing. Cavities were also prepared in amalgam blocks and sealed. Sealed specimens were thermocycled 100 times between baths of 1% methylene blue at 4°C and 60°C. Materials sealing satisfactorily at this stage were also tested similarly in composite resin blocks. Dimensional stability in water at 37°C at 24 Hours and 2 Weeks was assessed by measuring linear expansion. Wear was assessed on a brushing machine using Zircate paste as an abrasive.

Of the traditional restorative materials only Cavit was found to seal satisfactorily in all substrates as did the polyether based and epoxy based materials. TERM demonstrated the least linear expansion and Cavit the greatest with the majority of the Cavit expansion taking place in the first 24 hours. Permadyne showed the greatest wear resistance and Cavit the least. Subject to further usage and biocompatability studies filled polyethers and epoxy putties may be suitable as endodontic access seals.

This study was supported by an A.S.E. research grant.