



Invasive Cervical Resorption and Associated Endodontic Research

**Thesis submitted for the degree of Doctor of Dental
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Dedicated to my wife Helen.

DECLARATION

The studies presented in this thesis have been carried out solely by the author unless otherwise stated as collaborative studies. Collaborative studies have been delineated into those in which the author was (1) the principal investigator (2) a co-investigator or (3) not the principal investigator. In the last instance the author was generally involved in the conception of the research project, some supervision, evaluation of results and preparation of manuscripts.

None of the studies have been presented by the author for any other degrees.

Those studies in which the author was not the principal collaborative investigator formed the research component for the degree of Master of Dental Surgery for the principal authors of the published studies.

Signed

Witness \wedge

~~GEOFFREY SINCLAIR HEITHERSAY~~

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PRECIS

Studies by the author over the past 40 years are presented in this thesis as two complimentary components. Part 1, consists of a varied collection of works dating from 1959, the majority of which are of endodontic significance. Part 2 represents a study of invasive cervical resorption and its clinical management. Both research components embody the concept of lifetime dental health through the maintenance of the human dentition, which may be affected at some time by developmental defects, disease or trauma.

The research presented in Part 1 consists of 13 original studies in which the author was the sole, principal or co-investigator. The studies include physical dental anthropology, endodontic microbiology, physical properties of dentine, calcium hydroxide in endodontics, orthodontic extrusion of teeth, laser doppler evaluation of traumatised teeth, and endodontic education. Part 1 also details 17 collaborative studies in which the author was not the principal investigator. These have addressed several aspects of contemporary endodontic therapy by *in vitro* studies of root-canal irrigation, intra-canal medication with Ledermix paste— a corticosteroid antibiotic medicament used alone and in combination with calcium hydroxide, and calcitonin – a potential anti-clastic intra-canal medicament. Hydron, a poly-hydroxyethyl methacrylate root filling material has been investigated both *in vivo* and *in vitro* using a new cell culture technique while another *in vitro* study evaluated alternative temporary filling materials. The final studies in Part 1 examined tooth staining and the biochemistry of tooth bleaching.

Part 2 consists of six original publications of which the author was sole or principal investigator. These describe studies of invasive cervical resorption and its management. The clinical radiologic and histopathological features of invasive cervical resorption are detailed with particular reference to diagnosis and the significance of the complex resorptive process to treatment. Potential pre-disposing factors in the development of invasive cervical resorption have been analysed in 222 patients or 257 teeth. Each tooth was designated into one of four classes of severity, to allow a classification at the time of diagnosis which could then be related to the result of treatment. The majority of teeth at diagnosis fell into the third class. While several potential pre-disposing factors were identified, orthodontics, trauma and bleaching were those most frequently recorded in that order. A combination of factors, for example, trauma and bleaching, were considered significant. The incidence of bleaching related resorption was evaluated in a further study of 202 patients treated by a standardised bleaching method. Two patients (1.96%) showed the development of bleaching related invasive cervical resorption.

Tissue responses to the topical application of 90% trichloroacetic acid were assessed in an *in vivo* study in rats. The medicament was applied to the soft tissue of the palate and to wounds created at the tooth gingival margin into the periodontal ligament and adjacent bone. The results confirmed that trichloroacetic acid had properties, which could be utilized in the management of invasive cervical resorption.

A prospective study examined 94 patients with a total of 101 teeth displaying varying degrees of invasive cervical resorption treated by the topical application of trichloroacetic acid, curettage and restoration. Orthodontic extrusion was used as adjunctive therapy in some class 3 and class 4 cases. A minimum of three years follow-up was required unless failure occurred before that time in which case that treatment was included in that study. As a result of the investigation, it was apparent that successful treatment could be carried out in the first three classes of severity while alternative therapy was recommended in the fourth class.

The common link between the two thesis components is orthodontic root extrusion. Of the material presented in Part 1, orthodontic root extrusion is perhaps the most significant, while in Part 2 this adjunctive therapy enhanced the successful management of some of the more advanced cases of invasive cervical resorption. Today orthodontic root extrusion has become a mainstream adjunctive therapeutic measure in endodontic practices world wide.

INTRODUCTION

Over the past century there have been dramatic changes in dental health and dental attitudes within the Australian population. In the early part of the twentieth century indigenous Australian Aborigines generally showed excellent dental health with little evidence of caries or periodontal disease (Campbell 1925). However, with changing dietary patterns due to the contact with non-indigenous civilisation the caries incidence rose by the mid century (Cran 1955). This was confirmed by the author's own studies into the dental state of indigenous Australian Aborigines at Haast's Bluff, Central Australia in 1956 (Heithersay 1959).

By comparison, the dental health of non-indigenous Australians in the early to mid 1900's was generally poor with high caries rates (Cameron 1953) and apparently, but unconfirmed, extensive periodontal disease. "Pyorrhoea" was the reason given by many of the dental profession to justify the complete clearance of countless dentitions. Although conservative restorative dentistry was taught in dental schools, emphasis was placed on exodontia and full or partial denture construction as tooth loss was considered the long-term fate for most of the population.

Root canal therapy was practised to a very limited degree in Australia prior to the 1960's. Until that time treatment was generally confined to maxillary anterior teeth because of the perceived difficulty in cleaning and sterilising the complex root canal anatomy of other teeth in the human dentition.

Reflecting the teaching and practice of the time, Bloomfield (1947) wrote in the Australian Dental Journal:

"The limitations of the operator and the materials employed indicate root canal therapy for the six upper anteriors only; root canal fillings are contraindicated in every other tooth. Posteriors, both upper and lower, are contraindicated because no operator has the skill to work root fillings round corners or to fill elliptical canals with their weird twists, bends or sudden divisions, with any reasonable chance of success. Lower anteriors are contra indicated because the canals are too small and also because I am rather partial to having gravity on my side during draining and dressing."

Posterior teeth with pulp involvement due to dental caries were invariably condemned to extraction.

The introduction of water fluoridation, improved oral hygiene and fluoride toothpastes in the 1960's ushered in an era of preventive dentistry and with it came a change in community attitudes to dental health. The accent in teaching and practice changed to allow conservation, wherever possible, of the natural human dentition. The generations of Australians since that time have shown an extremely low incidence of dental caries (Carr 1982) making life-time retention of natural teeth a realistic expectation for the majority of this section of the population.

Despite the dramatic drop in dental caries, the dental health of an individual may be jeopardised by developmental, traumatic or pathological conditions in single or multiple teeth with trauma being the most common cause. In Australia, the incidence of minor or major dental trauma could be compared to Sweden, a similar society, where a study of 12 year-olds revealed that 39% of the group had suffered trauma to the teeth (Forsberg & Tedestam 1990).

Great advances have been made in the management of dental trauma particularly as a result of research into the areas of tooth and bone resorption. A lifetime commitment to such research and to the clinical management of dental trauma has been given by Dr Jens Andreasen of Copenhagen and his contribution to the study of dental traumatology is without parallel.

The author's own studies, over the past 40 years, have made some contributions to knowledge in the fields of dental epidemiology, pathology, microbiology, material science, pharmacology and particularly clinical endodontics. This thesis contains the principal original works which had as their broad aim the retention of the healthy human natural dentition throughout life. They are presented as two complimentary components. Part 1 consists of a varied collection of works, dating from 1959, the majority being of endodontic significance and Part 2 represents a study of invasive cervical resorption and its clinical management.

The studies presented in this thesis have been carried out solely by the author unless otherwise stated. Collaborative studies are delineated into those in which the author was (1) the principal investigator (2) a co-investigator (3) not the principle investigator. In the last instance the author was generally involved in the conception of the research project, some supervision, evaluation of results and preparation of manuscripts.

Review of authors studies

A chronological list of publications is shown in Appendix 1.



REVIEW OF AUTHOR'S STUDIES: PART 1

1 Studies in which the author was the sole investigator or the principal or co-collaborative investigator

1.1 Anthropological Research

Early studies arose from the author's participation in an anthropological expedition to Haast's Bluff, Central Australia in 1956. The expedition was led by Professor Andrew Abbie, Department of Anatomy, The University of Adelaide. A final year undergraduate student at the time, the author carried out extensive clinical observations and obtained impressions and casts of 115 dentitions. In addition, photographs and radiographs taken by other members of the expedition were subsequently examined.

The field material was assessed and analysed and the resultant research reports were published (Appendix 2 papers 1-3.) The first paper entitled "A dental survey of the Aborigines at Haast's Bluff, Central Australia" (Heithersay 1959) recorded both environmental factors and clinical and radiographic findings. Sixty four per-cent of subjects examined displayed dental caries, which indicated a significant decline in dental health from that observed in studies early in the twentieth century (Campbell 1925). Other observations were made with respect to the gingival and periodontal status and the degree of calculus formation. The incidence of tooth hypoplasia and variations in tooth anatomy were noted. The incidence of dental mutilations generally involving the ritual removal of a central incisor at the time of initiation of young males was recorded. The pattern of pigmentation at the muco-gingival region was also detailed.

A second study was entitled "Attritional values for Australian Aborigines – Haast's Bluff" (Heithersay 1960). The author introduced an attritional index which was a modification of the Broca classification, in general use at that time. The Broca classification had limitations when applied to the dentitions of indigenous Australian aborigines because no single Broca value could be given over several age groups. The attritional index was an attempt to overcome this limitation. Both occlusal and interproximal attrition was observed increasingly in all age groups, being higher in adult males than females.

The third study from the Haast's Bluff expedition was based on measurements made from 115 casts obtained from impressions taken in the field (Heithersay 1961). This study recorded external and internal arch widths, arch lengths and palate heights for males and females and the measurements were statistically analysed for sex differences. Occlusion for each subject was recorded according to Angle's classification.

All research material, including casts, photographs, and radiographs are now archived at the Aboriginal Research Centre in Canberra.

1.2 Endodontic Microbiology

Research carried out in the Department of Endodontics, Royal Dental School Malmö, Sweden in 1960-1961 addressed the possible contamination of root canal cultures taken during the microbiological sampling of root canals as part of endodontic therapy. Culturing of root canal samples was generally accepted and practised at that time in many countries of the world. However sampling and cultivation techniques had the potential for false positive or false negative results. A study in which the author was the principal investigator analysed the incidence of *Staphylococcus albus* (*Staphylococcus epidermidis*) and *Streptococcus salivarius* in 2652 bacterial cultures taken by students in the endodontic clinics at the Royal Dental School, Malmö (Heithersay & Bjerken 1962, Appendix 2, paper 4). *Staphylococcus albus* was present in 2.5% of all cultures or 7% of all positive cultures while *Streptococcus salivarius* was present 4% of cultures or 11.4% of all positive cultures. As both organisms were considered to be contaminants from hands or the oral cavity, the study gave an indication of the efficacy of the sampling techniques employed in the Malmö undergraduate endodontic clinics at that time. The contaminating role of these organisms was later confirmed by the extensive research of Møller. The present author assisted in the preparation of manuscripts for the publication of Møller's studies, which were entitled "Microbiological examination of root canals and periapical tissues of human teeth" (Møller 1966).

1.3 Heat transmission through dentine

A further research project in which the author was the principal investigator was carried out in Malmö in 1960-1961 (Heithersay & Brannström 1962, Appendix 2, paper 5) as part of a two-stage project which aimed to assess the effect of heat on the dental pulp. This was of significance at that time as high-speed handpieces were still in their infancy with coolant often being poorly provided by a single jet. A review of the literature indicated some practical problems in heat transmission experiments particularly with respect to the thermoelement used to record heat rise. This study assessed methods of applying heat to dentine samples *in vitro* and the effect of using silicone oil as an intervening medium. The temperature rise through dentin specimens of varying width was recorded following the application of a thermode at 150 °C for 5 seconds, 15 seconds and 30 seconds with or without an intervening medium.

Part 2 of the project was carried out by Dr Hilding Nyborg, Head of the Endodontic Department, Royal Dental School Malmö, but no results were ever published due to his failing health.

1.4 Calcium hydroxide studies

Dental trauma often affects children at an early stage of tooth development and frequently results in pulp necrosis which then requires complex treatment. Calcium hydroxide was first reported as an intra-canal medication to induce apex formation in incompletely developed teeth by Granath (1959) and subsequently a few early case reports of this clinical treatment emerged (Frank 1966, Michanowicz and Michanowicz 1968, Steiner et al. 1968).

In 1970, the author published the first analysis of 21 cases of incompletely developed pulpless teeth with associated periapical pathology treated with calcium hydroxide (Heithersay 1970, Appendix 2 paper 6). The observation times in the study varied from 14 months to 75 months. In addition to the analysis, which indicated a high success rate, the paper contained the first published histopathological material of an example of apexogenesis of a human tooth treated with calcium hydroxide.

The research thesis component for the degree of Master of Dental Surgery at the University of Adelaide in 1965 described the use of calcium hydroxide following partial pulpectomy. This was of particular significance to the treatment of incompletely developed teeth with a history of dental trauma and partial pulp necrosis.

“Calcium hydroxide in the treatment of pulpless teeth with associated pathology” was the subject of a subsequent publication by the author (Heithersay 1975, Appendix 2 paper 7). This paper highlighted the potential use of calcium hydroxide in several clinical situations which had not been previously documented. The overall clinical applications included (1) intra-canal anti-microbial medication (2) control of exudation (3) large periapical lesions (4) apical inflammatory root resorption (5) external inflammatory root resorption (6) apical internal resorption (7) internal/external root resorption (8) perforations (9) transverse root fractures, and (10) incompletely developed teeth. This paper expanded on the earlier study outlining the use of calcium hydroxide in the treatment of pulpless teeth with associated periapical pathology (Heithersay 1970) and described four different types of apical development.

1.5 Orthodontic root extrusion

The treatment of subgingival transverse root fractures by combined endodontic therapy, orthodontic tooth extrusion and prosthodontic reconstruction was developed by the author in 1969 and subsequently published (Heithersay 1973, Appendix 2, paper 8). This was the first report of such a combined treatment which made possible the retention of many teeth which would otherwise have been extracted. It was followed three years later by a similar report from Ingber (1976). At the time of presentation, the present author suggested that the technique could be used in a variety of complex dental situations where a tooth was subgingivally compromised. Resorptions, developmental defects, vertical root fractures and extensive caries were suggested as other possible clinical situations where orthodontic extrusion could be used to render a sub-gingival defect into a supra-gingival position. It is generally recognised that the avoidance of deep subgingival restorations is important from the point of view of long term periodontal stability.

A significant finding reported in the first publication was the transportation of the soft tissue attachment, periodontium and the supporting bone as orthodontic extrusion proceeded. This indicated a clinical application not only to allow the advantage of supragingival positioning of the defect but the potential to eliminate a localised bone defect. The utilisation of orthodontic extrusion as an aid to periodontal management of teeth with angular bone defects was subsequently and independently described by Ingber (1974).

A subsequent joint publication classified crown and crown root fractures and reviewed treatment alternatives highlighting the advantages of orthodontic tooth extrusion (Heithersay and Moule 1982, Appendix 2, paper 9).

The principle of orthodontic tooth extrusion of teeth compromised by the subgingival location of a fracture, resorption or developmental defect has been accepted and widely quoted. In one major endodontic text book – “Pathways of the Pulp,” a contributing author James Simon (1984) labelled the orthodontic extrusion of teeth as the “Heithersay approach”. Modifications to the original orthodontic technique have been described (Simon 1984, Malmgren et al.1991). The author’s own collaborative management has also changed with experience and new technologies over the past thirty-years. The present technique employed by the author and his collaborative orthodontist Dr Lester Duthy involves (1) the temporisation of the tooth crown with glass ionomer cement or a temporary crown where necessary, (2) the adjustment by grinding of the incisal edge and the occluding surface to allow an unimpeded extrusive movement, (3) placement of a bonded labial bracket to the affected tooth and several adjacent teeth, (4) light round wire activation to effect extrusion making sure of the correct axial alignment, and (5) further occlusal adjustment as the tooth is extruded to avoid any traumatic contact.

The active orthodontic extrusion is usually completed in 4-6 weeks. Following bracket removal, the extruded tooth is splinted to the adjacent tooth with bonded composite resin placed labially, lingually or palatally depending on the occlusal relationship and the aesthetic requirements. Gingivoplasty is usually required not only to restore a harmonious gingival contour but also to remove the free gingival fibres which have been implicated in relapse (Persson and Serneke 1977). If gingivoplasty is not required, pericision of the free gingival fibres is necessary. After 2 months the splint is removed on the assumption that the periodontal ligament has undergone re-orientation (Simon et al. 1980). Ideally, an aesthetically acceptable temporary restoration is then placed and left in position for approximately 6 months to allow complete stabilisation of the periodontal ligament prior to final restoration.

An as yet unpublished evaluation of 57 teeth which were orthodontically extruded is diagrammatically summarised in Appendix 2 paper 10. Table 1 shows the number of teeth relative to the follow-up periods which varied from 1-20 years (mean 5.1 years). The teeth which were extruded are shown in Table 2 the majority being maxillary central or lateral incisor teeth. The reasons for extrusion are shown in Table 3, which indicates that the majority were extruded because of sub-gingival root fractures. Table 4 shows the number of teeth which were extruded either by a rapid method over a period which varied from 2-12 weeks or a slow extrusion which varied from 16-36 weeks. Of the rapid extrusions Table 5 shows the distribution of treatment times, which ranged from 2-12 weeks (mean 7.2). A radiographic assessment of resorption is shown in Table 6, which indicated that there was no apical resorption or progressive root surface resorption with 52 teeth, which had been rapidly extruded. In teeth which had been slowly extruded apical resorption was evident in one tooth but this was considered stable and there was no evidence of progressive surface resorption. Failure occurred in five of the 57 teeth (8.8%) and the reasons for failure are shown in Table 7. Of the five failures one was due to a new

traumatic incident, two to root fractures and one to an undiagnosed root fracture. Table 8 shows the survival time of those teeth which had failed, and this varied from 3-7 years.

This study indicated a high success rate for orthodontic tooth extrusion and subsequent restoration. Rapid extrusion, which was shown to be effective, has the advantage of reduced treatment time and improved economics. This rapid method of root extrusion has been supported by the clinical study of Malmgren et al. (1991)

1.6 Laser Doppler assessment of traumatised teeth

The influence of a blood pigment layer on the clinical use of the Laser Doppler meter was co-investigated with Dr Robert Hirsch. The findings of that study (Heithersay and Hirsch 1993, Appendix 2, paper 8) are of importance in the evaluation of the pulpal blood flow in traumatised teeth by the use of Laser Doppler Flowmeter. It was shown that blood pigment deposited within dentinal tubules following dental trauma acts as a barrier to the transmission of the laser beam. Hence a negative reading with this device in a discoloured tooth may not be indicative of the state of the underlying pulp, which in the absence of other signs and symptoms of degeneration, may still be in a recovery stage. Unless the limitation of this new technology is recognised, an incorrect diagnosis may be made, and as a result, potentially unwarranted root canal therapy instituted.

1.7 Endodontic education

A study in 1974 evaluated endodontic treatments carried out by dental students at the Adelaide Dental School (Smales, Makinson and Heithersay, 1974, Appendix 3, paper 12). The study provided important information regarding the quality of treatment by undergraduates as well as tutor variability in their assessments of such treatments.

This was followed in 1975 by a study of undergraduate endodontic education in Australia (Heithersay and Mayne 1975, Appendix 2, paper 13). The study concluded that there was a need at that time to upgrade under-graduate endodontic education in Australia to meet Western world standards.

2 Collaborative studies in which the author was not the principal investigator

Abstracts of publications of these studies are provided in Appendix 3. The following aspects of endodontic therapy have been investigated:

2.1 Ledermix Paste

Ledermix paste a corticosteroid antibiotic combination has been used extensively in Australia since its introduction by Schroeder (1962). It has been used as a medicament in vital pulp therapy and also as an intra-canal medication in the control of acute periapical inflammation. It has also been used clinically in the treatment of inflammatory root resorption. As there was little research relating to Ledermix paste published prior to 1984 several collaborative investigations were initiated to provide a greater insight into its therapeutic properties. A study entitled "Release and diffusion through human tooth roots *in vitro* of corticosteroid and tetracycline trace molecules from Ledermix paste (Abbott, Heithersay and Hume 1988, Appendix 3, abstract 1) showed that significantly greater amounts of the corticosteroid tetracycline components of Ledermix paste were released through dentine to the external root surface than through the root apex. This was of relevance to the clinical use of Ledermix paste in the control of periradicular inflammation and also in the treatment of inflammatory root resorption. The study also recorded the rate of release of the components, which had clinical relevance to the desirable time intervals between root canal dressings.

A further study investigated barriers to the diffusion of Ledermix paste in radicular dentine (Abbott, Hume & Heithersay 1989a, Appendix 3, abstract 2). It focused particularly on irrigation regimes which might influence diffusion through dentine of both components of Ledermix paste. It also assessed diffusion when cementum was removed. The investigation showed that an irrigation regimen which involved the sequential use of 15% of ethylenediamine tetra-acetic acid combined with cetrime (EDTAC), 1% sodium hypochlorite (NaOCl), and 15 % EDTAC allowed an increase in the permeation of the trace molecules through dentine. The clinical removal of cementum also resulted in a significant increase in the permeation of the trace molecules.

A further study (Abbott, Hume, Heithersay 1989b, Appendix 3, abstract 3) investigated *in vitro* the release and diffusion through human coronal dentine of triamcinolone and demeclocycline from Ledermix paste. The results showed that the molecules readily diffused through dentine and reached to peak rate of diffusion at two hours. The rate then decreased exponentially with time. The data appeared to have clinical relevance and helped explain the therapeutic benefits of applying this medicament in cases of pulpitis.

Ledermix paste has been shown in *in vivo* studies (Pierce and Lindskog 1987) to have an anti-clastic action in teeth exhibiting inflammatory root resorption. An *in vitro* study (Pierce, Heithersay and Lindskog 1988, Appendix 3, abstract 4) used odontoclastic cells which had been grown for 24 hours on a nutrient culture medium which were then exchanged for either the antibiotic component demethylchlor-tetracycline, or a combination

of the antibiotic and the corticosteroid embodied in Ledermix paste. The cells were left for varying periods of up to 24 hours before fixation and examination under scanning electron microscope. While the clastic cells exposed to the antibiotic showed a characteristic “fried-egg” appearance indicating the clear zone of attachment for all experimental periods, cells exposed to Ledermix paste progressively become more spherical and ceased to spread along the coverslip, and by 18 hours no cells remained.

These studies confirmed existing clinical evidence that Ledermix paste was an effective agent when used in the treatment of inflammatory root resorption. The diffusion experiments confirmed that both components of Ledermix paste could diffuse through to the external surface aiding both in the elimination of infecting microorganisms and directly affecting the clastic cells involved in the inflammatory root resorptive process.

2.2 Ledermix paste and Calcium hydroxide

As many clinicians in the early 1980's advocated the use a 50:50 mixture of Ledermix paste and calcium hydroxide as an intra-canal medicament, it was thought desirable to investigate aspects of this combination. The effect of the combination on the diffusion of the corticosteroid tetracycline components through human tooth roots was investigated *in vitro* (Abbott, Hume, Heithersay 1989c, Appendix 3 abstract 5). This study showed that the release rates of trace molecules were lower when the mixture was used, compared with the release of Ledermix alone. The results indicate that this combination of materials may have practical benefits when used as a long-term intra-canal dressing.

A further *in vitro* study was carried out to assess whether the individual components of the Ledermix and calcium hydroxide mixture remained biologically active (Taylor, Hume and Heithersay 1989, Appendix 3, abstract 6). In this study diluents of Ledermix paste, Pulpdent paste and a mixture of equal parts by weight of Ledermix paste and Pulpdent paste (calcium hydroxide in methyl-cellulose) were added to *in vitro* cultures of mouse fibroblasts or bacteria for 24 hours. Various cells functions were examined, in particular mitosis in and the survival of the fibroblast cell line and the survival of *Lactobacillus casei* and *Streptococcus mutans*. The study showed that the 50:50 mix of Ledermix and Pulpdent retained the properties examined that are thought to be of therapeutic benefits while not increasing the toxicity of the component parts to mammalian cells. This study thus provided experimental evidence to support the clinical use of a Ledermix and calcium hydroxide mixture in various aspects of endodontic therapy when the anti-inflammatory anti-clastic properties of Ledermix paste and the anti-microbial properties of calcium hydroxide can be used to clinical advantage.

2.3 Calcitonin

This naturally elaborated polypeptide hormone has a regulatory function on clastic cells and has been shown *in vivo* to be an effective intra-canal medication in the control of inflammatory root resorption (Pierce, Berg and Lindskog 1988). The diffusion kinetics of calcitonin through tooth roots were investigated *in vitro* (Wiebkin Cardaci, Heithersay and Pierce 1996a&b, Appendix 3, abstracts 7 & 8). It was found that calcitonin placed within the root canal could be detected at the root surface after 2 hours but continued to be

detected for the nine days of the study. Furthermore, reversible binding of calcitonin to the dental mineral meant a slow release thus enabling it to exert a long acting effect on clastic cells. These studies indicated a clinical use for this substance but it has not yet been developed into a suitable form for therapeutic use in endodontic therapy.

2.4 Root canal irrigation

The removal of smear layer has generally been considered desirable in non-surgical root canal therapy to allow free access of intra-canal medicaments to dentinal tubules which may contain microorganisms. A study was carried out to confirm some preliminary findings of Blackler (1983) with respect to the sequential use of EDTAC and sodium hypochlorite in root canal irrigation. In this investigation six irrigation sequences were used alone and with ultra-sonic activation of a root canal file (Abbott, Heijkoop, Cardaci, Hume and Heithersay 1991, Appendix 3, abstract 9). Teeth were assessed for smear layer removal by scanning electron microscopic examination of the prepared root canal. The results showed that a smear layer was present after savlon had been used as an irrigant and this was not reduced with ultrasound. By contrast ultra-sound did improve cleansing with the other irrigation regimens. The most effective irrigation regimen for removing smear layer and other debris was sequential use of 15% EDTAC, 1% sodium hypochlorite and then a further rinse with EDTAC. The study was of significance in the routine preparation of root-canals for endodontic therapy and of particular significance when treating teeth with inflammatory root resorption where smear layer removal will allow a greater diffusion to the external root surface of the therapeutic agents embodied in Ledermix paste.

2.5 Hydron

Hydron, a poly-2-hydroxy-ethyl-methacrylate material, was introduced as an alternative root canal filling material in 1979 (Goldman et al.1979). Polymerisation of the material occurs within the root canal. The manufacturers[♦] stated that the material was hydrophilic and would absorb fluid from the periapical tissues. Subsequent expansion of the material was expected to further enhance its sealing compacity. It was decided to investigate this material *in vivo*, *in vitro* and clinically.

Tissue responses to Hydron were assessed by intra-muscular implantation into the quadriceps muscle of guinea pigs (Reid, Wilson, Heithersay & Heijkoop 1992a, Appendix 3, abstract 10). Fully set AH26 and Teflon were used as controls. All materials were characterised by peri-implant connective tissue capsule formation but, in the case of Hydron implants, Von Kossa-positive material was observed at the implant tissue interface. The amount of this calcified material increased with time. Inflammation was not a predominant tissue response for any of the test materials nor was a foreign body giant cell response.

In a further study (Reid, Wilson, Heithersay & Heijkoop 1992b, Appendix 3, abstract 11), Hydron was assessed following intra-osseous implantation. Teflon tubes containing either freshly mixed, polymerised Hydron root filling material, fully set AH26, or Teflon alone,

[♦] N.P.D. Dental Systems Inc., Melville, NY, USA

were implanted into the mandible of guinea pigs and assessed histologically at follow-up periods of up to 26 weeks. While none of the materials tested elicited signs of overt or significant tissue damage, Hydron was assessed as having a similar biocompatibility to that of fully set AH26 or Teflon. Of significance was the observation of bone formation in close apposition to the polymerised Hydron compared with a soft tissue capsule which separated regenerated bone from the AH26 and Teflon implants.

In a further study (McNamara, Heithersay and Weibkin 1992, Appendix 3, abstract 12), a new *in vitro* biotoxicity test system was developed and used to assess cell responses to Hydron, AH26 and Tubliseal. The test system developed for this study was a modification of that described by Wennberg et al (1979). It was found that polymerising and pre-polymerised Hydron depressed both cell division and the secretion of matrix material. When compared with other root-filling materials, Hydron was found to have similar properties to those of Tubliseal but showed a greater inhibition of biosynthesis than noted for AH26. In general, the results indicated that Hydron, particularly in its freshly mixed state, depressed cell division and extracellular-matrix synthesis when not in actual cell contact.

The clinical study (Reid, Abbott, McNamara and Heithersay 1992, Appendix 3, abstract 13) examined Hydron root canal fillings over a five-year period and compared them with conventional gutta-percha-AH26 root canal fillings. Results indicated that both Hydron and gutta-percha – AH26 root canal fillings were well accepted, but, on the basis of radiographic assessment, success with gutta-percha-AH26 was more predictable.

The Hydron studies were important as they provided an independent assessment from that of the original investigators who also introduced this material onto the commercial market. Hydron was not a commercial success and is no longer available.

2.6 Tooth discoloration

Tooth discolouration following trauma is a significant clinical problem which can also have adverse psychological effects on the traumatised patient. An *in vitro* histochemical study of tooth discolouration by blood was carried out (Marin, Bartold and Heithersay 1997, Appendix 3, abstract 14). The study evaluated tooth samples in which whole blood, erythrocytes, plasma and platelet concentrate were introduced into pulp chambers and subsequently centrifuged. The study confirmed that staining was due to erythrocytes, and histochemical evaluation showed that, following haemolysis of erythrocytes within dentine, haemoglobin was found either intact or as one of the haematin molecules. There was no evidence of any free ferric ions or haemosiderin.

2.7 Intra-coronal bleaching

Harrington and Natkin (1979) first reported invasive cervical resorption which followed intra-coronal bleaching of root-filled teeth with hydrogen peroxide and since that time there have been several additional reports. To assess the potential role of hydroxyl radicals in this process, a study was carried out to determine whether hydroxyl radicals are generated through the bleaching of root-filled teeth which have been discoloured by blood

(Dahlstrom, Heithersay, Bridges 1997, Appendix 3, abstract 15). Teeth experimentally discoloured by blood were 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 the reaction products of this radical with salicylate using high performance liquid chromatography and electrochemical detection (HPLC – ECD). There was a significant association between the production of hydroxyl radicals and the presence of discolouration caused by blood components. The 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 thermocatalytic bleaching of root-filled teeth and this may provide one possible explanation of periodontal tissue damage and root resorption after thermocatalytic intra-coronal bleaching.

In an attempt to develop alternative bleaching techniques, a further study evaluated traditional and non-peroxide bleaching agents in teeth stained with blood (Marin, Heithersay & Bridges 1998, Appendix 3, abstract 16). Colour changes using various agents were recorded using a Reflection Densitometer. Alternative systems included a combination of three enzymes (amylase, lipase and trypsin) with disodium edetate. Although this was shown to be less effective than routine bleaching agents, the combination did have a modifying affect on the bloodstain. The most efficient bloodstain removal occurred with 30% hydrogen peroxide while sodium perborate comparatively proved to be 75% as effective.

2.8 Temporary endodontic seals

Effective endodontic temporary seals are important to avoid bacterial leakage particularly when using calcium hydroxide, Ledermix paste or their combination as long term intra-canal medicaments. Currently, a double seal of Cavit* and a more wear-resistant material such as a glass ionomer cement are recommended to avoid bacterial leakage between treatment sessions. As there are occasionally some practical problems with the current temporary endodontic seals, this investigation assessed the suitability of dental materials not customarily used as restorative materials and some epoxy based industrial materials. The study (Heijkoop, Heithersay & Makinson 1990, Appendix 3, abstract 17) showed that Cavit was the only traditional temporary filling material which sealed satisfactorily but it showed poor wear resistance. Both polyether and an epoxy resin-based material performed well compared with traditional materials, and it was concluded that, subject to further usage and compatibility tests, these materials would be suitable temporary endodontic seals.

* ESPE, GmbH & Co, Seefeld/Oberbay, Germany

REVIEW OF AUTHOR'S STUDIES: PART 2

1 A study of invasive cervical resorption and its clinical management

1.1 Clinical prologue

In 1977 a 14 year-old female patient was referred to the author for the management of an extensive external resorptive defect in a lateral incisor which had been observed by her orthodontist following orthodontic treatment.

It was the application of orthodontic extrusion in this case that exposed the variety of clinical problems associated with the treating this type of root resorption, and subsequently led to the clinical use of aqueous trichloroacetic acid as an adjunctive chemical agent.

The patient had just completed 2 years of orthodontic treatment using edgewise fixed appliances. On removal of the brackets the orthodontist took post-treatment photographs and radiographs of her maxillary and mandibular incisors (Figures 1-4).



Figure 1: Facial view of 14-year-old female at the completion of orthodontic treatment.



Figure 2: Labial view of dentition. No external evidence of resorption can be seen.



Figure 3: Palatal view of dentition.



Figure 4: Radiograph taken at the time of orthodontic appliance removal. An irregular, mottled, radiolucency on the mesial aspect of the maxillary left lateral incisor extends to the crown and the root.

He noted an irregularity on the mesial surface of the maxillary left lateral incisor (Figure 4) which had not been present on pre-treatment radiographs. There was a "mottled" appearance on the radiograph extending into the crown of the tooth and 3-4 millimetres below the level of the crestal bone which radiographically appeared to be intact. The pulp space was largely separated from the image of the lesion by a radio-opaque line but there appeared to be connections with the root canal both at the coronal and apical extensions of the lesion. Several radio-opaque lines could be seen within the defect with interspersed radiolucent areas.

A diagnosis of invasive cervical resorption was made. Because of the extent of the lesion, it was decided to carry out non-surgical root canal therapy and root canal filling and then orthodontically extrude the tooth to relocate the resorptive process into a supragingival position. Orthodontic extrusion was carried out over the next 4 months (Figure 5), followed by periodontal surgery involving flap reflection, curettage and gingival recontouring by a specialist periodontist.



Figure 5: Radiograph of the maxillary left lateral incisor after non surgical root canal therapy and orthodontic extrusion.

While the periodontist reported satisfactory healing of the gingival soft tissues on removal of the orthodontic bracket, he noted a series of “pink spots” on the labial surface. These proved to contain highly vascular tissue, which bled freely on probing. Clearly active resorption arising from the periodontal ligament was still occurring. It was concluded that treatment up to this stage had been unsuccessful. This was a great disappointment to all involved – the orthodontist, the periodontist, the author (an endodontist), and particularly the young patient who had been so tolerant of such extensive treatment carried out over the years. To be faced with extraction and a partial denture or bridgework (suitable implants were not available at that time) was devastating.

It was, as a last resort, that the author applied theoretical knowledge gained as an undergraduate pertaining to the chemical agent trichloroacetic acid. Pharmacological teaching at the Dental School, University of Adelaide had described trichloroacetic acid as a chemical escharotic agent which produces a limited layer of tissue necrosis without eliciting an underlying inflammatory response. Later studies by the author established that

this description had no experimental basis but was clearly the result of astute clinical observations.

After discussions and approval by the patient and her mother, it was decided to try to inactivate the resorptive tissue contained within the deeply infiltrating channels by selectively applying 90% aqueous trichloroacetic acid.

Fine pieces of cotton wool saturated with trichloroacetic acid were inserted into the resorptive channels after the orifices had been enlarged with small round burs. Figure 6 shows the labial surface of the maxillary lateral incisor after treatment of two channels, and sealing with Cavit, while a third channel remains at this stage untreated.

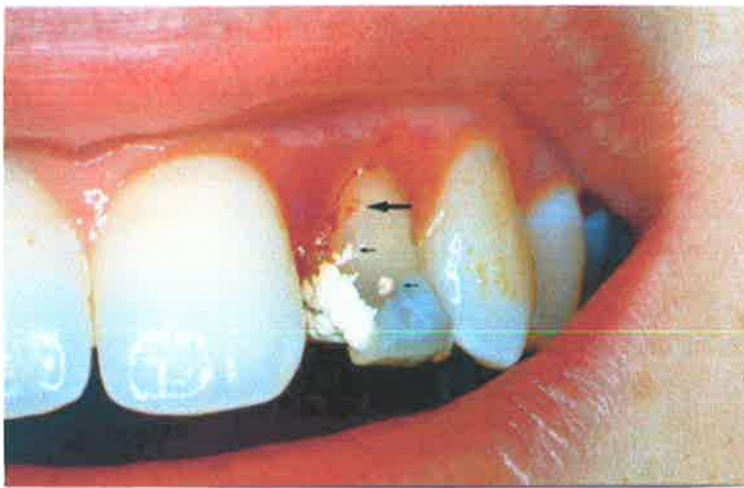


Figure 6: The labial surface surface of the lateral incisor shows Cavit on the mesial surface and in two treated channels (small arrows). An untreated vascular channel can be seen near the gingival margin (large arrow).

During treatment, the fine cotton pieces were inserted as deeply as possible. The effect of trichloroacetic acid on the resorbing tissue was rapid, evidenced by a lack of bleeding and obvious tissue necrosis. Nine days later the channels were re-entered but there was no sign of active tissue. Trichloroacetic acid was again applied to the channels.

The patient was observed over the next 15 months during which time there was no radiographic or clinical evidence of further resorption. A small periapical response became evident and so the canal was re-treated and re-sealed (Figure 7). The clinical state of the tooth at that stage is shown in Figure 8.



Figure 7: Radiograph taken after re-treatment of the root canal of the lateral incisor.



Figure 8: Labial view of the lateral incisor 15 months after initial treatment showing a satisfactory gingival state.

Discolouration of the crown had occurred but otherwise the tooth appeared to be free of pathology. Two years after her initial treatment, crown therapy which consisted of a cast gold post core and a porcelain fused to gold crown was carried out by a prosthodontist, and an excellent aesthetic result was achieved (Figure 9). A radiograph of the tooth taken at that time is shown in Figure 10.



Figure 9: Labial view after the completion of crown therapy.



Figure 10: Radiograph of the lateral incisor at the completion of crown therapy.

This patient has been reviewed regularly since that time both clinically and radiographically and at her last examination in 1996 (19 years since initial presentation) the lateral incisor was free of obvious pathology (Figure 11). In addition, the original crown remained in an excellent state both aesthetically and functionally (Figure 12). The long term success of this complex resorption treatment has been most rewarding for both the patient and the present author.



Figure 11: Facial view of the patient in 1996 19-years after her initial treatment.



Figure 12: Radiograph of the lateral incisor at the 1996 review.

The treatment of this patient stimulated the author's further interest in this challenging type of resorption. As a result, pharmacological, epidemiological, histopathological and prospective clinical studies have been carried out over the past 22 years with the aim of providing further knowledge as to the nature of this resorptive process and its clinical management.

1.2 Introduction

Invasive cervical resorption is an insidious and often aggressive form of external root resorption which has been of interest to clinicians and researchers over the past century. This external periodontally-derived root resorption is often recognised clinically as a pink discolouration near the cemento-enamel junction, a characteristic which has caused some confusion as the original description of teeth with "pink spots" by Gaskell (1894) and Mummery (1920) labelled this type of resorption as idiopathic internal resorption. Confusion still exists with many clear examples of invasive cervical resorption in current dental literature being diagnosed as internal resorption. The differential diagnosis of a pulpally derived internal resorption from the periodontally-derived external root resorption is very important if there is to be an appropriate form of therapy.

Although many terms have been listed over the years to describe this condition, "invasive cervical resorption" has been adopted by the author as it is descriptive both of the initial location of the resorption, at or near the cemento-enamel junction, and the invasively destructive nature of the lesion. Two other terms are in common usage at the present time: "extra-canal invasive resorption" (Frank 1987) or simply "cervical resorption" (Tronstad 1988, Trope 1994). While the former term was introduced to emphasise the external, periodontal origin of the resorptive tissue and the fact that it generally surrounds the root canal, it is, nevertheless, not descriptive of more advanced lesions where such invasion of the root canal does occur. The latter term "cervical resorption" is ambiguous as it can apply to cervical inflammatory resorption, which has a different pathological manifestation.

Invasive cervical resorption is fortunately uncommon in humans and has generally been observed in patients with a history of orthodontic treatment, trauma or bleaching. Interestingly this condition also occurs in cats and occasionally in dogs.

Following the initial clinical experience described by the author above, a literature review at that time revealed a diversity of views as to the nature of this resorptive process and its management. The most significant paper in the review was that of Makkes and van Velzen (1975) who demonstrated histopathologically the external periodontal origin of this type of resorptive process.

A review of the literature describing tissue reactions to trichloroacetic acid produced only one small dermatological study (Ayers 1960). All previous knowledge regarding the soft tissue responses to trichloroacetic acid had obviously been based on macroscopic observations.

Clearly there was a need for more information regarding the nature of invasive cervical resorption, its aetiology or potential pre-disposing factors, and its management. As

trichloroacetic acid was to be applied in the treatment of invasive cervical resorption there was also a need for an *in vivo* study to assess the responses of oral soft tissues, pulp, periodontal ligament and supporting bone to this chemical agent.

1.3 Aims of studies

The aims of this series of studies of invasive cervical resorption were as follows:

- To describe the clinical radiologic and histopathologic features of invasive cervical resorption
- To assess potential pre-disposing factors to the development of Invasive cervical resorption
- To investigate the tissue responses to the topical application of 90% aqueous trichloroacetic acid
- To prospectively study the results of treatment of invasive cervical resorption by the topical application of 90% aqueous trichloroacetic acid, curettage and restoration.

These were addressed in the following Publications (Papers 1-6).

1. Clinical, radiologic, and histopathological features of invasive cervical resorption
2. Invasive cervical resorption: An analysis of potential predisposing factors
3. Incidence of invasive cervical resorption in bleached root-filled teeth
4. Tissue responses in the rat to trichloroacetic acid
5. Treatment of invasive cervical resorption
6. Invasive cervical resorption following trauma

1.4 Materials and Methods

1.4.1 Clinical studies

The clinical material for these studies was based on patients who were specifically referred to the author's specialist endodontic practice because of invasive cervical resorption. Case histories were recorded and patients were examined visually, radiographically and with tactile probing and sensibility tests. The affected teeth were recorded photographically.

The clinical classification shown diagrammatically in Figure 13 was formulated and used in the studies. Four classes were defined.

Class 1 – Denotes a small invasive resorptive lesion near the cervical area with shallow penetration into dentine.

Class 2 – Denotes a well-defined invasive resorptive lesion that has penetrated close to the coronal pulp chamber but shows little or no extension into the radicular dentine.

Class 3 – Denotes a deeper invasion of dentine by resorbing tissue, not only involving the coronal dentine but also extending at least to the coronal third of the root.

Class 4 – Denotes a large invasive resorptive process that has extended beyond the coronal third of the root.

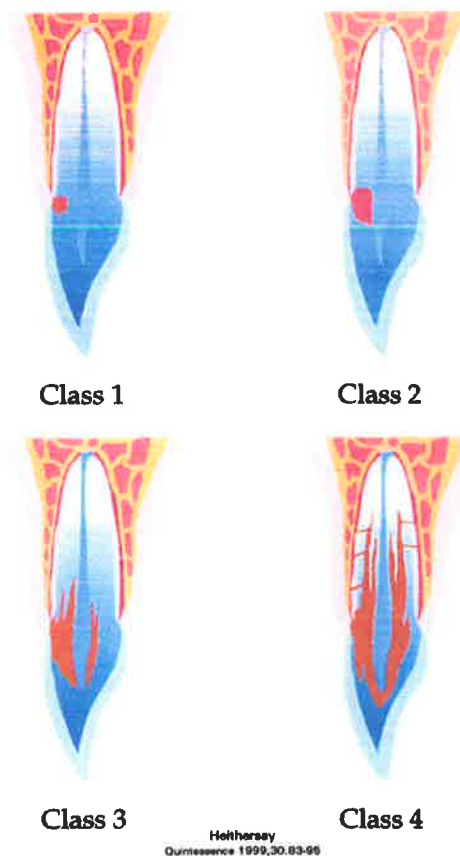


Figure 13: Clinical Classification

All patient details were entered into a computer database which recorded their age, sex, tooth or teeth affected, potential pre-disposing factors, treatment details and follow-up examinations. A coding system for potential pre-disposing factors was used to facilitate the recording of teeth for which several potential pre-disposing factors were identified.

The retrospective evaluation of bleaching related invasive cervical resorption involved all patients treated in the author's practice by a standardised thermocatalytic-walking bleach technique. Pre-treatment and follow-up radiographs of patients were examined using enhanced vision and illumination.[†] The level of the gutta-percha and AH26 root filling was assessed radiographically and recorded along-with any radiographic signs of invasive cervical resorption.

The treatment of various classes of invasive cervical resorption by the topical application of trichloroacetic acid, curettage and restoration was recorded photographically and radiographically. When adjunctive orthodontic therapy was used it was monitored in the same manner. Patients were recalled at six-monthly and yearly intervals for three years, and thereafter at two or three year intervals. Follow-up examinations were carried out radiographically, photographically, visually and with tactile probing, radiographically and photographically. A minimum of three years follow-up was required, unless failure occurred before that time in which case that treatment was included in the study.

1.4.2 Experimental studies

The *in vivo* study to investigate tissue responses to the topical application of trichloroacetic acid used male rats (Sprague-Dawley, Porten stain) as the experimental animal. Ninety percent trichloroacetic acid was applied topically to two test sites for a period of 30 seconds using small cotton pellets which had been moistened in the solution and then dampened on gauze. Test site 1 was the midline of the junction of the soft and hard palate and test site 2 consisted of a cavity prepared to a depth of 3 millimetres commencing at the palato-gingival margin between the first and second molar teeth and cutting down into the underlying periodontal ligament bone and tooth.

Twenty-eight rats were treated and were killed by anaesthetic overdose at control periods varying from 5 minutes to 42 days. Specimens were placed in 10% buffered formalin within 30 seconds and fixed for 48 hours. They were then decalcified using Decal II.[‡] After trimming, the specimens were prepared for histological evaluation using a double embedding technique with 20% Celloidin followed by Paraplast Plus.[§] The teeth were sectioned at 5 μ and stained with haematoxylin and eosin. All sections were then viewed microscopically[¶] and recorded photographically where indicated.

Teeth used for histopathological evaluation were extracted with minimal force, trying wherever possible to avoid forceps application to the cemento-enamel junction region. The teeth were placed in 10% buffered formalin immediately following extraction. Specimens were fixed, decalcified and prepared for histopathological evaluation as described above.

[†] Oi laminex AB.

[‡] Surgipath Products, Medical Industries Inc., Illinois, USA.

[§] Monoject Scientific, Division of Sherwood Medical, St Louis, USA

[¶] Olympus BH2 microscope, Olympus Optical Co. Ltd., Japan.

A study of invasive cervical resorption and its clinical management

1.5 Publications (Papers 1 – 6)

1. Clinical, radiologic, and histopathological features of invasive cervical resorption
2. Invasive cervical resorption: An analysis of potential predisposing factors
3. Incidence of invasive cervical resorption in bleached root-filled teeth
4. Tissue responses in the rat to trichloroacetic acid
5. Treatment of invasive cervical resorption
6. Invasive cervical resorption following trauma

These publications are included in the print copy
of the thesis held in the University of Adelaide Library.

Volume 1

Paper 1

Heithersay, G. S. (1999). Clinical, radiologic, and histopathologic features of invasive cervical resorption. *Quintessence International*, 30(1), 27-37.

Paper 2

Heithersay, G. (1999). Invasive cervical resorption: An analysis of potential predisposing factors. *Quintessence International*, 30(2), 83-95.

Paper 3

Heithersay, G., Dahlstrom, S., & Marin, P. (1994). Incidence of invasive cervical resorption in bleached root-filled teeth. *Australian Dental Journal*, 39(2), 82-87.
<https://doi.org/10.1111/j.1834-7819.1994.tb01378.x>

Paper 4

Heithersay, G., & Wilson, D. (1988). Tissue responses in the rat to trichloroacetic acid - an agent used in the treatment of invasive cervical resorption*. *Australian Dental Journal*, 33(6), 451-461.
<https://doi.org/10.1111/j.1834-7819.1988.tb05849.x>

Paper 5

Heithersay, G. (1999). Treatment of invasive cervical resorption: An analysis of results using topical application of trichloroacetic acid, curettage, and restoration. *Quintessence International (Berlin, Germany : 1985)*, 30(2), 96-110.

Paper 6

Heithersay, G. (1999). Invasive Cervical Resorption Following Trauma. *Australian Endodontic Journal*, 25(2), 79-85.
<https://doi.org/10.1111/j.1747-4477.1999.tb00094.x>

1.6 Results and Discussion

Paper 1 (Heithersay 1999a) describes the clinical, radiologic and histopathological features of invasive cervical resorption. Of significance are the radiologic appearances when related to the histopathological features of the resorptive process as it progresses from being fibro-vascular in origin to fibro-osseous. As the invasion of the dental pulp occurs only late in this process the radiographic image of the intact root canal outline provides a further diagnostic criterion applicable to this condition. Potential difficulties in treatment of the later stages of invasive cervical resorption were related to histopathological observations where there was evidence of a dynamic interface between tooth and the resorbing tissue. This is shown by the bone-like material laid directly onto resorbed dentine and the channels containing fibrovascular tissue which not only inter-communicate with the periodontal ligament but also extend into the radicular root structure. These features are of basic clinical importance, as successful treatment requires total inactivation of all resorptive tissue.

Paper 2 (Heithersay 1999b) analysed potential pre-disposing factors in 222 patients with a total of 257 teeth displaying varying degrees of invasive cervical resorption. The results indicated a strong association between invasive cervical resorption and orthodontic treatment, trauma and intra-coronal bleaching either alone or in combination. The other potential pre-disposing factors identified in order of incidence were: surgery, periodontal therapy, bruxism, delayed eruption, developmental defects and interproximal stripping.

A significant finding was that the majority of patients in the study presented with Class 3 resorptions. Obviously, earlier diagnosis at a Class 1 or 2 stage would have been desirable, as treatment of these lesions is less complicated.

The clinical relevance of the study is that dentists should be alert to the possibility of invasive cervical resorption, especially following trauma, intra-coronal bleaching, or orthodontic treatment alone or in combination with these factors. Periodic radiographic checks are necessary for those teeth that might be considered to be at risk.

The preceding non-randomised study gave a frequency of intra-coronal bleaching related invasive cervical resorption in 4.5% of patients (3.9% of teeth) and, when combined with other factors, particularly trauma, in 14.9% of patients (13.6% teeth).

Paper 3 (Heithersay 1999c) reported a further study in which the author was the principal investigator where the incidence of invasive cervical resorption in bleached root-filled teeth was assessed for 158 patients with a total of 204 teeth. All patients had been treated by the author in his private specialist endodontic practice using a standardised combined thermocatalytic and "walking bleach" technique. The results revealed that four teeth (1.96%) had developed bleaching related invasive cervical resorption. All four teeth had a history of trauma and root-treatment prior to the bleaching procedure. Although this study indicated an incidence which was lower than that previously reported, (Friedman et al. 1988), further investigations into alternative non-thermocatalytic methods of bleaching have been carried out.

Collaborative research reported in part 1(b) provided a likely reason for the initiation of bleaching related resorption (Dahlstrom, Heithersay & Bridges 1997, Appendix 3, abstract 14). Production of hydroxyl radicals at the root surface during the thermocatalytic bleaching of blood stained teeth was demonstrated in this study. Hydroxyl radicals, a species of free oxygen radicals, are characterized by their destructive action on connective tissue, and in the case of a bleached tooth, the periodontal ligament. An alternative method of non-thermocatalytic bleaching using thiourea to act as both a bleaching agent and a scavenger of hydroxyl radicals has been developed by the author and will be the subject of further research reports.

An *in vivo* study in which the author was the principal investigator is shown in Paper 4 (Heithersay & Wilson 1988). This study investigated the tissue responses in the rat to the topical application of trichloroacetic acid and confirmed previous clinical observations that 90% aqueous trichloroacetic acid applied to oral mucosa resulted in a limited zone of coagulation necrosis. This was followed by oedema, splitting, and separation of the eschar and rapid re-epithelization within two days. Of significance was an almost complete absence of underlying inflammation. In addition, there were no essential differences in the healing of trichloroacetic acid wounds into deeper dental tissues compared with control wounds. This study confirmed a rational basis for the clinical application of trichloroacetic acid in the treatment of invasive cervical resorption. The medicament could be expected to produce a limited zone of coagulation necrosis within the active resorbing tissue and yet should not adversely affect adjacent periodontal tissues.

Paper 5 (Heithersay 1999c) reported a prospective study of 101 teeth with varying degrees of invasive cervical resorption treated by the topical application of 90% aqueous solution of trichloroacetic acid, curettage, non-surgical root canal treatment where necessary, and restoration with glass ionomer cement. Adjunctive orthodontic extrusion was used in 10 teeth displaying class 3 resorption and one class 4 case.

The mean follow-up periods for the classes 1- 4 were 4.5, 8, 5.5 and 5.4 years respectively.

The results showed that the treatment regimen was 100% successful in Class 1 and Class 2 cases. The results of Class 3 resorption treatment showed a 96.8% control of resorption. When all pulpal, periapical and periodontal factors and tooth loss due to root fracture were assessed, the overall success rate was 77.8%. Orthodontic extrusion used in 15.9% of teeth treated enhanced the success rate, and further use of this adjunctive treatment may have resulted in a higher success rate for Class 3 resorptions.

The study showed that, while the treatment of Class 4 cases resulted in tooth retention for at least five years, the overall success for this class was poor and positive clinical recommendations were suggested. In some situations, no treatment is a reasonable alternative as the progressive resorption may be slow and the patient may have several years of useful tooth function before it is necessary to extract the tooth. When there has been a communication with the oral cavity, extraction and prosthodontic replacement are indicated. While bridgework and partial dental prostheses still have a place in current treatment, implant therapy is generally the method of choice. While implant therapy must

be a considered treatment alternative for patients showing both Class 3 and Class 4 resorptions, the success rate of the treatment of Class 3 lesions shown in this study is acceptably high when all factors have been assessed, and compares favourably with a recently published lifetable assessment of implant therapy (Roos et al 1997).

This study also showed that orthodontic extrusion could enhance the success rate for treatment of Class 3 lesions by re-positioning the base of the resorptive cavity into a supragingival position. Not only does this provide better access for resorption treatment, but it also allows for the placement of a restoration which will be conducive to the maintenance of gingival and periodontal health. Extrusion also improves the crown-root ratio, which should impact on long-term tooth stability. It has additional benefits if there has been localised bone loss as this will be restored by normal inductive processes initiated from the periodontal ligament as its attachment follows the root as it is extruded.

The various success rates shown in the study led to the conclusion that diagnosis and treatment at the earliest stage of invasive cervical resorption is highly desirable.

Paper 6 (Heithersay 1999d) is a supplementary paper dealing specifically with invasive cervical resorption following trauma, and concludes that patients who have a potential for the development of invasive cervical resorption by virtue of a history of trauma should be monitored radiographically throughout life.

Concluding remarks

When the author first developed the concept of orthodontic tooth extrusion for the management of teeth with subgingival fractures, the treatment of a number of other conditions including various tooth resorptions had been envisaged. It is rewarding that the original idea of orthodontic tooth extrusion has led to the development of an effective method of treating invasive cervical resorption. Furthermore, the interaction of the two treatment modalities has allowed the possibility of successful therapy for many patients affected by the more extensive manifestations of this insidious and challenging pathological condition.

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Over my life-time in dentistry which has concentrated on the field of endodontology there have been many teachers and colleagues to whom I owe a great debt of gratitude. Professor Andrew Abbie (deceased) opened my undergraduate eyes to research. In Edinburgh, Professor John Boyes (deceased) and Dr David Middleton (deceased) provided contrasting theoretical and clinical experience in oral medicine and oral surgery. In Sweden, Dr Hilding Nyborg (deceased) Head of the endodontic department, University of Lund, Royal Dental School, Malmo was a fine mentor in endodontic theory and research. His friendship and that of Professor Bo Krasse and Professor Hans Grahnen and other colleagues at the Royal Dental School in Sweden will always be treasured. I was also privileged to have worked with Dr Martin Brannstrom and Professor Ake Moller.

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BIBLIOGRAPHY

ABBOTT, P.V., HEIJKOOP P.S., CARDACHI, S.C., HUME, W.R. and HEITHERSAY, G.S. (1991).

An SEM study of the effects of different irrigation sequences and ultrasonics.
Int. Endod. J. 24:308-316.

ABBOTT, P.V., HEITHERSAY, G.S. and HUME, W.R. (1988)

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

Endod. Dent. Traumatol. 4:55-62.

ABBOTT, P.V., HEITHERSAY, G.S. and HUME, W.R. (1989a)

Barriers to diffusion of Ledermix paste in radicular dentine.

Endod. Dent. Traumatol. 5:98-104.

ABBOTT, P.V., HEITHERSAY, G.S. and HUME, W.R. (1989b)

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

Endod. Dent. Traumatol. 5:92-97.

ABBOTT, P.V., HEITHERSAY, G.S. and HUME, W.R. (1989c).

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

Endod. Dent. Traumatol. 5; 188-192.

BLACKLER, S. (1982)

A scanning electron microscopic study of the prepared root canal.

M.D.S. Thesis. University of Sydney.

BLOOMFIELD, A.J. (1947)

Root canal therapy.

Aust. Jour. Dent. 51:312-316.

CAMERON, D.A. (1953)

An investigation of the caries experience and diet of groups of school and pre-school children in Sydney (1946-1947).

Dent. J. Aust. 25:50-56.

CAMPBELL, T.D. (1925)

Dentition and palate of the Australian Aboriginal.

Keith Sheridan Foundation Publication No 1. Adelaide, The University of Adelaide.

CARR, L.M. (1982)

Dental health of children in Australia 1977-1980.

Aust. Dent. J. 27:169-175.

-
- CRAN, J.A. (1955)
Notes on the teeth and gingivae of Central Australian Aborigines.
Aust. Jour. Dent. 59:356-61.
- DAHLSTROM, S.W, HEITHERSAY, G.S. and BRIDGES, T.E. (1997).
Hydroxyl radical activity in thermo-catalytically bleached root-filled teeth.
Endod. Dent. Traumatol. 13:119-125.
- FORSBERG, C. and TEDESTAM, G. (1990)
Traumatic injuries to teeth in Swedish children living in an urban area.
Swed. Dent. J. 14:115-122.
- FRANK, A.L. (1966)
Therapy for the divergent pulpless tooth by continued apical formation.
J. Amer. Dent. Ass. 72:87-93.
- FRANK, A.L. and BLAKLAND L.K. (1987)
Supra osseous extracanal invasive resorption.
J. Endod 13:348-387.
- FRIEDMAN, S., ROTSTEIN, I., LIBFIELD, H., STABHOLZ A., and HELING, I. (1988).
Incidence of external root resorption and esthetic results in 58 bleached pulpless teeth.
Endod. Dent. Traumatol. 4:23-6.
- GASKILL, J.H., (1894).
Report of a case of internal resorption.
Dent. Cosmos. 36:1019-1024.
- GOLDMAN, L.B., GOLDMAN, M., KRONMAN, J.H. and KLIMENT, C. (1979)
The use of a hydrophillic plastic as a root canal filling material – delivery system and technique.
Quint. Int. 10:101- 107.
- GRANATH, L.E. (1959)
Nagra synpunkter pa behandlingen av tramatiserade incisiver pabarn.
Odontol. Revy 10:272.
- HARRINGTON, G.W. and NATKIN, E. (1979).
External resorption associated with the bleaching of pulpless teeth.
J. Endod. 5:344-348.
- HEIJKOOP, P.S. HEITHERSAY, G.S. and MAKINSON, O.F. (1990).
Dental and industrial materials as temporary endodontic access seals.
J. Dent. Res. 69;4:Abs 17.

HEITHERSAY, G.S. (1959)

A dental survey of the Aborigines at Haast's Bluff, Central Australia.
Med. Jour. Aust. 1:721-729.

HEITHERSAY, G.S. (1960)

Attritional values for Australian Aborigines, Haast's Bluff.
Aust. Dent. J. 5:84-88.

HEITHERSAY, G.S. (1961)

Further observations on the dentition of the Australian Aborigines at Haast's Bluff.
Aust. Dent. J. 6:18-28.

HEITHERSAY, G.S. (1973)

Combined endodontic-orthodontic treatment of transverse root fractures in the region of the alveolar crest.
Oral. Surg. 36:404-415.

HEITHERSAY, G.S. (1970).

Stimulation of root formation in incompletely developed pulpless teeth.
Oral. surg. oral. med. oral. path. 29;4: 620- 630.

HEITHERSAY, G.S. and BJERKEN, E. (1962).

The incidence of Staphylococcus Albus and Streptococcus Salivarius in root canal cultures.
Odont. Revy 13;2;152-157.

HEITHERSAY, G.S. and BRANNSTROM, M. (1963)

Observations on heat-transmission experiments with dentin.
I. Laboratory Study.
J. Dent. Res. 42:1140-1145.

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.

HEITHERSAY, G.S. and MAYNE, J.R. (1975)

Endodontic Education.
I. Undergraduate.
II. Postgraduate and graduate.
Aust. Dent. J. 20:311-315.

HEITHERSAY, G.S. and WILSON, D.F. (1988).

Tissue responses in the rat to trichloroacetic acid – an agent used in the treatment of invasive cervical resorption.
Aust. Dent. J. 33:451-461.

INGBER, J.S. (1974)

Forced eruption: Part I. A method of treating isolated one and two wall infrabony osseous defects – rationale and case report.

J. Periodontol. 45:199-206

INGBER, J.S. (1976)

Forced eruption: Part II. A method of treating nonrestorable teeth – periodontal and restorative considerations.

J. Periodontol. 47:203-216.

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.

MAKKES, P.C. and THODEN VAN VELZEN, S.R. (1975).

Cervical external root resorption.

J. Dent. 3:217-222.

MALMGREN, O, MALMGREN, B. and FRYKHOLM, A. (1991)

Rapid orthodontic extrusion of crown root and cervical root fractured teeth.

Endod. Dent. Traumatol. 7:49-54.

MALMGREN, O., MALMGREN, B. and GOLDSSEN, L. (1994)

Orthodontic management of the traumatised dentition.

In: (Eds) Andreasen, A.O. and Andreasen, F.M. Textbook and Color Atlas of Traumatic Injuries to the Teeth, Ed 3. Copenhagen: Munksgaard, 603-606.

MARIN, P.D., BARTOLD, P.M. and HEITHERSAY, G.S. (1997).

Tooth discoloration by blood: an in vivo histochemical study.

Endod. Dent. Traumatol. 13:132-138.

MARIN, P.D., HEITHERSAY, G.S. and BRIDGES., T.E. (1998).

A quantitative comparison of traditional and non-peroxide bleaching agents.

Endod. Dent. Traumatol. 14:64-67.

MICHANOWICZ, J.P. and MICHANOWICZ, A.E. (1968)

A conservative approach and procedure to fill an incompletely formed root using calcium hydroxide as an adjunct.

J. Dent. Child. 34: 47-54.

MOLLER, A.J.R. (1966)

Microbiological examination of root canals and periapical tissues of human teeth.

Scand. Dent. J. 74:No 5&6.

MUMMERY J.H. (1920).

The pathology of "pink spots" on teeth.

Br. Dent. J. 41:301-311.

-
- PERSSON M, and SERNEKE, D. (1977)
Ortodontisk framdragnig av tand med cervikal rotfraktur for att mojliggora kronersattning.
Tandlakartidningen. 69: 1263-1269.
- PIERCE, A.M., and LINDSKOG, S. (1987).
The effect of an antibiotic/corticosteroid paste on inflammatory root resorption in vivo.
Oral. Surg. Oral. Med. Oral. Pathol. 64:216-220.
- PIERCE, A.M., BERG, J.O. and LINDSKOG, S. (1988)
Calcitonin as an alternative therapy in the treatment of root resorption.
J. Endod. 14:459-464.
- 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.
- REID, R.J., ABBOTT, P.V., MCNAMARA, J.R., and HEITHERSAY, G.S. (1992).
A five-year study of Hydron root canal fillings.
Int. Endod. J. 25:213-220.
- REID, R.J., WILSON, D.F., CHAU, K.K., HEITHERSAY, G.S. and HEIJKOOP, P.S. (1992a).
Tissue responses to Hydron, assessed by intramuscular implantation.
Int. Endod. J. 25:199-204.
- REID, R.J., WILSON, D.F. CHAU, K.K., HEITHERSAY, G.S. and HEIJKOOP, P.S. (1992b).
Tissue responses to Hydron, assessed by intraosseous implantation.
Int. Endod. J. 25:192-198.
- ROOS, J., SENNERBY, L., LEKHOLM, U., JEMT, T., GRONDAHL, K. and ALBREKTSSON, T. (1997).
A qualitative and quantitative method for evaluating implant success: A 5-year retrospective analysis of the Branemark Implant.
Int. J. Oral. Maxillofac. Implants 12:504-514.
- SCHROEDER A. (1962)
Cortisone in dental surgery.
Int. Dent. J. 12:356-373.
- SIMON, J.H.S. (1984)
Orthodontic-Endodontic treatment.
In: Pathways of the Pulp. Eds: Cohen S. and Burns R.C., C.V. Mosby Co., St. Louis., USA, 680-691.

-
- SIMON J.H.S., LYTHGOE, J.B. and TORABINEJAD, M. (1980)
Clinical evaluation of extruded endodontically treated teeth in dogs.
Oral. Surg. 50: 361-371.
- SMALES, R.J., MAKINSON, O.F. and HEITHERSAY, G.S. (1974)
An analysis of endodontic treatment at a dental school.
Aust. Dent. J. 19:25-31.
- STEINER, J.C., DOW, P.R. and CATHEY, G.M. (1968)
Inducing root end closure of non-vital permanent teeth.
J. Dent. Child. 35: 47-54.
- TAYLOR, M.A., HUME W.R. and HEITHERSAY G.S. (1989)
Some effects of Ledermix paste and Pulpdent paste on mouse fibroblasts and on bacteria in vitro.
Endod. Dent. Traumatol. 5:266-273.
- TRONSTAD, L. (1988)
Root resorption – Etiology, terminology and clinical manifestations.
Endod. Dent. Traumatol. 4:241-252.
- TROPE, M and CHIVIAN, N. (1994).
In: Cohen S, Burns R, (eds). Pathways of the Pulp, ed 6. St Louis: Mosby 493-503.
- WEIBKIN, O.W., CARDACI S.C., HEITHERSAY, G.S. and PIERCE, A.M. (1996a).
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.
- WEIBKIN, O.W., CARDACI S.C., HEITHERSAY, G.S. and PIERCE, A.M. (1996b).
Therapeutic delivery of calcitonin to inhibit external inflammatory root resorption.
II. Influence of calcitonin binding to root mineral.
Endod. Dent. Traumatol. 12:272-276.
- WENNBERG, A., HASSELGREN, G. and TRONSTAD, L. (1979).
A method for toxicity screening of biomaterials using cells cultured on millipore filters.
Jour. Biomed. Mats. Res. 13:109-120.