A Clinical Study to Determine the Factors That May Influence Results in Non-Surgical Endodontic Retreatments.

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Compared to constant taper

Abstract

When faced with a failing or failed root treatment, the dentist must decide whether the tooth can be retreated and saved or extracted. The dentist's decision to retreat is often based on the x-ray presenting a failing root treatment. The dentist must be aware that there might be a number of factors that have contributed to the failure and which may preclude, following retreatment, a successful long term clinical function.

The current study has been made to determine those factors that may influence the prognosis in order to assist the clinician in advising the patient of the best course of treatment.

A literature review was made to determine and identify these factors and explain their relevance and influence on the healing process. The current study included identifying the factors described in the literature review and noting their influence on the prognosis following non-surgical retreatment.

Retreatment of failed root treated teeth requires special knowledge and skill from the clinician in order to correct and manage the case. The current study was made in a clinical setting and compared results of retreatment with two types of rotary files on the market: progressive or variable taper (ProTaper) with constant non-ISO 06 taper (K3). Clinical signs and symptoms were noted at the patient's presentation and following recalls at 1, 4 months and 1 year. The results were recorded and statistically analysed and the results were discussed.

The results showed that out of 81 patients 10 cases of retreatment were considered to have failed and 68 cases were considered to have been successful. Three patients did not return for their assessments and were therefore not considered in further results.

There was a statistically significant ($p<0.10$) recording of deep periodontal pockets associated with teeth with failing root treatments (40%) and (13%) in the "Success" group. The two estimated proportions of "Sinus" present (60%) in the "Failure"

group and 10% in the 'Success' group were significantly different (p<0.01). "Sinus present" in the "Success group" means in the initial clinical assessment *before* retreatment was initiated. The presence of a sinus at the One Year follow up signified a failure of the root retreatment (p<0.001). The two estimated proportions of "Occlusion" present (80% and 99%) in the "Failure" and "Success" group were significantly different (p<0.05). Therefore, teeth in "occlusion" were more within the "Success" group. 70% of those teeth that failed had pretreatment apical rarefactions of greater than 6mm diameter; whereas 76.5% of successful retreatments had areas less than 6mm diameter. The differences were significant according to Fisher's Exact Test (p<0.01). 44% of failed cases had areas of rarefaction described as "diffuse"; and 56% of failed cases had areas that were described as "well-defined". 95% of cases that were successful had areas described as "diffuse" and the rest were "well-defined". The differences between the success and failure categories were statistically significant (p<0.01). The two estimated proportions of "Post present" (0% and 31%) in the "Failure" and "Success" groups were significantly different (p<0.10). Therefore, the "Post was present" in many more cases within the "Success" group than in the "Failure" group. There was no difference between the Median "Crown/Root" ratios of the "Failure" (Median = 0.595) or "Success" groups (Median = 0.662) (Wilcoxon Test, p>0.10). Teeth with longer roots tend to lead to failure, however there was a considerable overlap between the distributions. Therefore the finding is that the Median length of the roots of the "Failures" is longer than that of the "Successes". (Wilcoxon Rank Sum Test, p-value = 0.0628). The results also indicated that previous short root filling *preparation* contributes to the final success of retreatment (Fisher Exact Test, p<0.05). There was a significant difference between the distribution of the "Failure" and "Success" (88.2%) groups (Fisher Exact Test, p<0.01) in those cases with initial short obturated fillings. When comparing the outcome following the use of the two types of rotary files it was found that the "Successes" with K3 File (35 out of 41) was 85%; and with Protaper File (32 out of 36) 89%. The "Success" rate certainly was not different between the two file types.

The conclusions drawn from the current study was not significantly different from those in the literature review and the overall results were of a similar nature with some minor changes. However it is clear that non-surgical root retreatment offers a good prognosis and should be included as an option for failed or failing root treatment.

DECLARATION

I declare that *A Clinical Study to Determine the Factors That May Influence Results in Non-Surgical Endodontic Retreatments* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Gary Zolty Date: March 2010

Signed:

Contents

Introduction

Endodontic treatment has had a phenomenal effect on humankind, in that millions of teeth have been saved following the now standard care of dental root treatment. Unfortunately there have been a related number of failures. The dentist, together with the patient, will then be faced with an option of retreatment or extraction and possibly replacement (Ruddle CJ, 2004).

The dental community needs to assist the dentist to decide the best avenue of treatment after root treatment failure. This study will look at the factors related to the cause of root canal failure and compare the factors that might be related or influence the prognosis following retreatment. Armed with this information the dentist will then be better informed to make decisions of the possible retreatment option. The patient has the right to know the prognosis of the proposed treatment as a component of informed consent. Clinicians must be able to provide this information to the patient based on the best available data (Paik *et al*, 2004).

When faced with a failing root treatment, the issues that should be considered by the dentist when choosing between retreatment and extraction are:
What are the "root" causes of root treatment failure and can they be corrected? Is it practically possible to treat? Factors that must be considered are the cost factor, time to treat and the tooth's restorability? The tooth's periodontium must be evaluated for supporting tissues, crown/root ratio and alveolar bone support. A cracked root may be picked up following periodontal pocket investigation which would preclude retreatment. The dentist must consider the risk of further failure with added costs of retreatment verse an alternative to retreatment which might be more predictable (Stroumza JH, 2005). Non-surgical retreatment as opposed to surgery should be evaluated and the best outcome advised and explained to the patient.

Further, the patient's needs and desires should be surveyed as well as his or her overall expectations. Does the patient understand the prognosis for the tooth and want to attempt retreatment (personal communication Ruddle CJ, October, 2004). The dentist must be trained for the additional skills and knowledge required and gain confidence, with particular cases or refer to a specialist in order to obtain the best prognosis (Ruddle CJ, 2001a).

Before we can answer why the root treatment failed we need to look at how we determine that the treatment has failed. The American Association of Endodontists considers a case to be clinically successful when there are no adverse signs or symptoms and the tooth is in normal function. There should be no tenderness to percussion or palpation, any swelling, sinus tract formation or abnormal mobility. Clinical failure is indicated by "persistent subjective symptoms, developement of a sinus tract or swelling, discomfort to percussion or palpation or excessive mobility and periodontal breakdown" (Quality assurance Guidelines. Third Edition 1998, American Association of Endodontists). The stress is on the clinical and subjective appraisal.

A review of the literature will demonstrate initially a more objective, stringent and limiting definition with regard to which root treatment is successful or has failed and then later to more inclusive, subjective and clinical or functional appraisal.

Chapter 1

Literature review

Success appraisal and results

Although the following description of success appraisal is not current, it remains as the standard by which objective studies are based upon. Strindberg LZ, (1956) assessed his results by reviewing the radiographs and classified them as successful (a) when the "contours, width and structure of the periodontal margin were normal" or (b) when the "periodontal contours were widened mainly around the excess filling". They were described as failures (a) when the "area of periadicular rarefaction was only diminished; (b) when there was unchanged periradicular rarefaction; or (c) when there was an appearance of new rarefaction or an increase in the initial". Uncertain results were when there was "ambiguous or technically unsatisfactorily control radiographs which could not for some reason be repeated".

Later, Bender *et al*, (1966a); Adenubi JO and Rule DC (1976) suggested that the criteria of success for endodontic treatment should include a clinical and more realistic appraisal, although not all inclusive or conclusive, such as:

1) "Absence of pain or swelling
2) Disappearance of fistula
3) No evidence of tissue destruction
4) No loss of function
5) Radiographic evidence of an eliminated or arrested area of rarefaction after a post treatment interval 6 months to 2 years.
6) An intact lamina dura"

The criteria for failed root treatment were:

1) "when there were symptoms even if the radiographs appeared satisfactory,
2) when an area (of radiolucency) persisted or increased in size,
3) when an area appeared on the radiograph where none had been present either initially or at the completion of treatment";

The appraisal was considered "doubtful":

> "when the tooth was symptomless and in normal function, but where an area of periapical radiolucency present at beginning of treatment was reduced or had disappeared but no lamina dura had reformed".

When assessing the success of root treatment according to these strict criteria, it was found that root treatment had an overall failure rate of about 12% (Grahnén H and Hansson L (1961) and Ng *et al* (2007a). It is noteworthy that through the review of literature this figure changed only a few percentage points depending upon the clinicians and study performed. It may be argued that the reason the success results have not changed much through the years may be due to the dentist's selection of more difficult cases (Ng *et al*, 2007a). Certain factors will be traced and shown that results would hinge on the obturation fill and other factors, for example, Harty *et al*, (1970) indicated that the risk of failure of root fillings may also be due to the incomplete obliteration of accessory canals. Other factors may not be included in certain number of the studies, and so it is difficult to directly assess and compare the results. In fact, the review of the literature shows, for example, those studies do not take into account the influence of the preparation methods with the same attention. A number of studies look at contributing factors or some of which account for a multiple of factors contributing to the success or failure of root treatments. However, a common thread of evidence was shown that if there was no overextension, the failure frequency is smallest. And following this, if roots were not reamed through the apex, the tooth had better results. This was particularly significant in vital teeth. Ideally the root filling should finish flush with the apex of the tooth when viewed in the radiograph or just short of the apex (Seltzer *et al*, 1963; Adenubi JO and Rule DC, 1976; Kojimi *et al*, 2004). It is axiomatic that root fillings that were well laterally compressed produced highly significant satisfactory results when compared with poorly compressed root fillings. There is also a clear tendency that vital teeth had less failure frequency than with non-vital teeth when root treated, perhaps since non-vital teeth are often infected (as opposed to Strindberg LZ, 1956, results).

A significant finding through the literature was the reduced healing when a pulpless tooth was treated with an area present (Adenubi JO and Rule DC, 1976 and Basmadjian-Charles *et al* (2002). On the basis of the review by Ng *et al* (2007b), they found that there was no difference in the outcome of treatment on teeth with different sizes of lesions; but the time taken to heal would take longer in cases with larger periapical lesions.

Following the above clinical challenges of ensuring a root filling is without voids and extends to within 2mm of the apex, the clinician may also need to deal with the pre-operative presence of a periapical lesion. We will also later discuss the fact that a good sealing coronal restoration may affect the success outcome. All of these challenges have also to take into consideration the anatomical complexity of the root canals. It is therefore clear that the factors involved in the particular case may affect the outcome and offer varying results. The same procedure of cleaning, shaping and packing of the canal is repeated for two distinct entities: (1) the vital but diseased pulp; where the goal is to maintain existing periapical health and prevent periapical disease; or (2) the non-vital or dying pulp associated with periapical disease where the goal is to restore periapical health (Ng *et al*, 2007b).

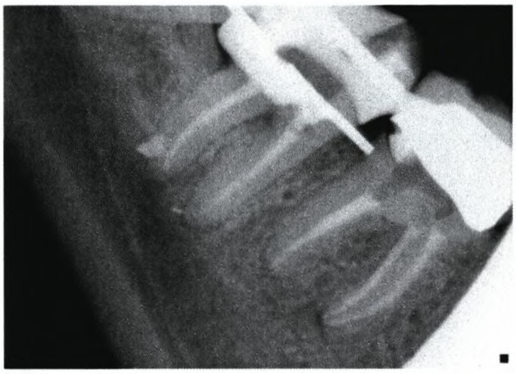
Differences in the length of observation time used for the evaluation of success can produce variations in the rate of success or failure. Also the different observation criteria of success (e.g. decrease in size of lesion, or complete bone regeneration) provided variations when studied at different time intervals. It was observed that failures would occur within a 2 year period, whereas the clinical symptoms of pain, swelling and development of a fistula will occur during treatment or within the first few months after treatment. But as the time interval increased following treatment, the results of root treatment improved (Bender *et al*, 1966a; Harty *et al*, 1970, Adenubi JO and Rule DC, 1976).

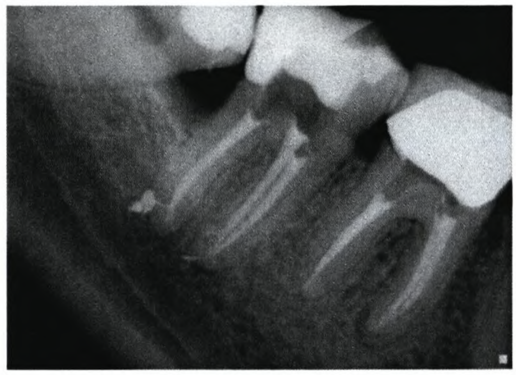
Paik *et al*, (2004) showed that there have been very few research studies in the past 34 years with a high level of evidence for the outcome of endodontic retreatment, but all of the studies have shown that retreatment offers a decreased prognosis when compared to initial root canal treatment.

X-ray determination

Observing x-rays in the clinical setting is the "standard by which success can be compared or appraised over a given period of time. In general, rarefaction visible in radiographs corresponds to the histological picture of pathologic changes. Only in few cases a small area of rarefaction on a radiograph corresponds to scar tissue with the structure of connective tissue and no symptoms of inflammation" (Strindberg LZ, 1956).

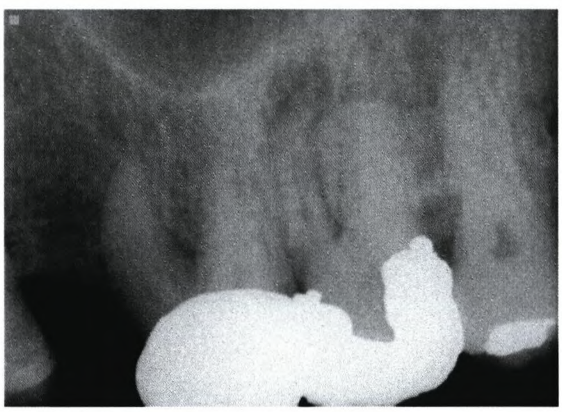
Bender *et al*, (1966b) have made an attempt to correlate clinical, histological and radiographic observations of endodontically treated teeth in order to focus attention on the inadequacies of radiographic studies as the sole criterion of treatment success. They have argued that interpretations of success vary among clinicians and most often rely on the radiograph alone. "The inconsistencies of evaluating x-rays may be due to factors such as differing contrasts of films and angulations, personal bias of the clinician or evaluators". Radiographic interpretations of radiolucencies present many fallibilities. (Priebe *et al*, 1953; Seltzer S and Nazimov H, 1965; Selzer *et al* 1967a; Morton TH Jr., 1979; and Smulson M, 1984)





Note the size and shape of the apical rarefaction related to the mesial roots of tooth no. 46. The angulation of the x-ray appears to have an influence on the size and shape.

It has been shown that a histological investigation of periapical tissue showing chronic inflammation with necrotic pulps may present clinically with normal radiographic findings. However, areas of rarefaction only appear on the radiograph when the lesions encroach on the junction area of cancellous and cortical bone. When this junction area or cortical bone is destroyed, the lesion can be visualized on the radiograph (Bender *et al*, 1966b; and Laskin D, 1964).



Note the apical rarefaction related to MB root of tooth number 27 and the deep ***distal*** restoration.

It is imperative to determine the true cause of the rarefaction on the radiograph as other causes may be due to systemic and local constitutional disorders. Periodontal disease often causes radiographic lesions and some clinical features, such as dental pain, that are mistaken for evidence of endodontic treatment failure. These lesions develop either before or after endodontic treatment (Bender *et al*, 1966a).

In conclusion, when assessing the prognosis or success/failure appraisal it is necessary to take all clinical signs and symptoms as well as radiographic indices into account before making a conclusion of the outcome of treatment. The appraisal must be made through a consistent follow up period of at least 2-4 years.

The bacterial implication- the sum of all causes of root treatment failure

The debate that bacteriological control has a direct influence on the outcome of root treatment extends from 1951 (Hedman WJ, 1951, Engström *et al*, 1964) until recently. This principle was checked in various studies with proponents for (Zeldow BJ and Ingle JI, 1963; Engström, *et al*, 1964; Byström *et al*, 1987; and Sjögren *et al*, 1997) and against (Seltzer et al, 1963).

However, the virulence and the quantity of microorganisms which are found in the infected root canal and the periapical area have been found to be the main instigator for periapical lesions and flare-ups following root treatment (Zeldow BJ and Ingle JI, 1963).

"Microbial flora of treated canals could be characterised as mono-infections of predominately gram-positive microorganisms, with approximately equal proportions of facultative and obligate anaerobes. Untreated canals, in comparison have a polymicrobial flora with approximately equal proportions of gram-negative and gram-positive bacteria and are dominated by obligate anaerobes". (Byström A and Sundqvist G, 1981)

An earlier study by Engström *et al*, (1964), showed that failure of root treatments were associated with the "bacteriological culture of 20-30% concentration of *streptococcus* species; and those with successful outcomes with staphylococcus species". This may possibly indicate that staphylococci in root canal are not pathogenic.

Later studies (Molander *et al*, 1998; Siqueira JF Jr. and Rocas IN, 2004 and Stuart *et al*, 2006) revealed that facultative anaerobe species predominated and *Enterococci* were the most frequently isolated.

Sixty per cent of the instrumented canals in the study by Sjögren *et al*, (1997) were bacteria-free by the end of the first appointment, which corroborates earlier work on the effectiveness of instrumentation with sodium hypochlorite (Foley *et al*, 1983). There was no indication in this study that specific bacteria were resistant to the biomechanical treatment. However, Sjögren *et al*, (1997), advocates multiple appointments with interappointment dressings to totally eliminate microorganisms.

Sundqvist *et al*, (1998), looked at the success of retreatment and to identify the factors that might influence the prognosis. All the teeth studied showed radiographic evidence of periapical lesions. Apart from one case that had been poorly root treated, all teeth had been root filled up to a reasonable radiographic standard. The previous root fillings were removed without chemical solvents. Bacterialogical samples were taken after the first and second appointment (7 days later) and then the teeth were dressed with calcium hydroxide. At the third and final appointment the root filling by cold lateral condensation was performed.

The bacterial species recovered from 24 of 54 canals after removal of the previous root filling showed that "in 19 cases a single species was present, in 4 cases there were two species present (*Streptococcus intermedius* and *Lactobacillis. catenaforme, Eubacterium alactolyticum* and *Propionibacterium acnes, P. micros* and *S. mitis, P. micros* and *F. nucleatum*), and in one case there was a polymicrobial infection consisting of four species (*S. anginosus, Eubacterium timidum, Propionibacterium propionicum* and *Bacteroides gracilis*). In all nine cases in which *Enterococcus faecalis* was isolated, it was the only microorganism present in the canal".

The success rate achieved following the retreatment was judged to be 74%. The success rate of cultivated and nil bacteria after cleaning the canals was the same. Teeth that tested positive for *E. faecalis* after removal of the earlier root filling resulted in lower (66%) success rates. Those teeth that failed following retreatment contained *E. faecalis* and the fourth root canal harboured *Actinomyces israelii*. When no microorganisms were cultivated at the time of root filling, 35 of 44 teeth healed – success rate of 80%. The initial size of the periapical lesions appeared to have an influence on the outcome of retreatment where the larger the lesion; the poorer the result. The mean size of all initial lesions was 4.2mm. The results of this study (in Sundqvist *et al*, 1998), show that a high percentage of cases with previous root fillings and persisting periapical lesions can be successfully managed by conservative endodontic retreatment. Siqueira JF Jr. *et al* (2008) recommend that evidence based anti-microbial strategy is performed when treating teeth with apical periodontitis in order to improve the outcome.

To summarise, most treatment failures are caused by microorganisms persisting in the apical parts of the root canal system.

Enterococcus faecalis

Enterococcus faecalis is a persistent organism that, despite making a small proportion of the flora in untreated canals, plays a major role in the etiology of persistent periradicular lesions after root canal treatment (Sundqvist *et al*, 1998). It is commonly found in a high percentage of root canal failures and it is "able to survive in the root canal as a single organism or as a major component of the flora" (Stuart *et al*, 2006). It competes with other bacteria and may form biofilms which are difficult to penetrate.

Preparing the apical portion of the root canal to a larger instrument size will help eliminate intracanal microorganisms and allow for the irrigation fluid to reach those areas. Besides the conventional irrigant of sodium hypochlorite (NaOCl) of three percent to full strength, Chlorhexidine in a 2% gel or liquid concentration (for 2 minutes), is effective at reducing or completely eliminating *E. faecalis* from the root canal space and dentinal tubules. The canals must be irrigated in adequate amounts and exchanged regularly to optimise the potency and destroy *E. faecalis.* Combinations of 2% chlorhexidine and calcium hydroxide have been shown to totally eliminate *E. faecalis* species from within the dentinal tubules. AH plus epoxy resin based sealer and Sultan zinc oxide-eugenol based sealer both exhibit "good antibacterial effects" against *E. faecalis*. (Cobankara *et al*, 2004). Based on these studies it can be concluded that a combination of adequate instrumentation and appropriate use of irrigants, medicaments and sealer will optimise the chances of eradicating *E. faecalis* during retreatment of failed root canal cases.

To help reduce the number of microorganisms while treating the tooth, the patient may be asked to "rinse with chlorhexidine before treatment, disinfecting the tooth and rubber dam with chlorhexidine or sodium hypochlorite and disinfecting gutta percha points with sodium hypochlorite before inserting in the canal" (Stuart *et al*, 2006). Generally facultative anaerobic bacteria are less susceptible to antimicrobial activities than anaerobes and therefore can be expected to persist more frequently in the root canal following inadequate treatment procedures. Pinheiro *et al*, (2003a) and Pinheiro *et al*, (2003b) suggest that an "individual" strategy based on a bacterialogical diagnostic test should be preferred to a standardized approach to their antibiotic sensitivity.

Another approach would be to look at the whole obturation seal to eliminate the ingress of microorganisms after treatment. Newer obturating systems such as Epiphany have been designed to bond to the root canal walls and thus prevent bacterial leakage. A study has been made to compare the leakage in a fluid-transport method from roots obturated with gutta percha and AH26 or AH plus sealant cements with Epiphany sealer and Resilon core material. The teeth filled with gutta percha and AH26 exhibited the most leakage. The least leakage was seen with Epiphany sealer and Resilon core material. Preliminary studies suggest that this system is better at preventing microleakage of *E. faecalis* than gutta percha filled canals (Shipper *et al*, 2004). Other studies may show contrary results (Fransen *et al*, 2008), but the attention to this requirement of controlling microleakage is in the right direction.

Mechanical preparation or filing the root canal walls will only remove those bacteria that it reaches, therefore chemical elimination by means of irrigation fluids will be needed to reach those areas that are impossible to clean mechanically. Torabinejad *et al*, (2003b) demonstrated that a new detergent solution (a mixture of a tetracycline isomer, an acid and a detergent, (MTAD) was "much more effective in eliminating microorganisms and in particular *E. faecalis* and with minimal damage to host tissues when compared to sodium hypochlorite (NaOCl) solution and ethylene diamine tetra-acetic acid (EDTA)". The effectiveness of MTAD does not diminish with 200X dilution. Also it was found that it was effective in killing E. faecalis after exposure of 2 or 5 minutes.

In summary, a thorough cleansing of the canal with the supporting action of disinfection would be necessary for successful removal of the bacteria from the root canal for the best results of root canal treatment.

The influence of microbioti or others in apical lesions

Shovelton DS (1964), showed that bacterial invasion of dentine does not occur with an acute apical abscess, but is seen in dentine within a tooth with chronic infection.

Grossman *et al*, (1964), Dow PR and Ingle JI (1955) agree that irritation of *any* kind such as chemical from irrigational fluids or extrusion of medicaments can produce bone changes and necrosis, resulting in an area of rarefaction or can prevent repair in such an area. So factors that may contribute to a persistent periradicular infection after root canal treatment include "intraradicular infection, extraradicular infection, foreign body reaction and cysts containing cholesterol crystals" (Fleming PS, 2003). Other reasons why root treatments fail may include the fact that bacteria organise into biofilms that are resistant to biomechanical treatment. The fact that granulomatous tissue which is often present associated with root apices, in itself is inflammatory tissue and therefore may produce bony necrosis and rarefaction. Periapical lesions which fail to heal despite careful bacteriological monitoring of the endodontic treatment may in some cases be due to an establishment of the bacteria outside the root canal in the periapical tissue. In these sites, the bacteria are inaccessible to conventional endodontic treatment (Byström *et al*, 1987). Some bacterial species are capable of survival outside the root canal in the peri-radicular tissues inducing periapical pathology such as *Actinomyces spp.* and *Propionibacterium propinicum* (Fleming PS, 2003).

In conclusion, there are many factors, excluding microbiota, that may account for root treatment failure and all these sources must be considered before retreating a failed root treated tooth.

The smear layer factor

The complete efficacy of chemomechanical preparation of the root canal system has long been in doubt. Many standard techniques in endodontics produce a canal wall, which is smeared, often coated with contaminants. This layer is unsatisfactory for mechanical or chemical bonding purposes to affect an efficient seal and in fact the smear layer must prevent chemical cleaning to get to the underlying bacteria present in the dentinal tubules (McComb D and Smith DC, 1975). In an in vitro study they demonstrated by use of a scanning electron microscopy (SEM) that the smeared layer was not firmly attached to the underlying dentine. A further identification they made was that reaming and filing alternately resulted in a canal that was more uniformly instrumented and enlarged than when either reaming or filing alone. They noted that when RC-prep (RC-prep is a commercial EDTA preparation in a paste form) was used in conjunction with 6% sodium hypochlorite, a smeared surface with much superficial debris resulted. A smooth and superficially clean canal was produced with the liberal use of sodium hypochlorite alone during and after instrumentation. The smear layer was still present but superficial to this canal. Though teeth treated with REDTA and left in the canal for 24 hours produced the cleanest canal walls (McComb *et al*, 1976; Sleiman P and Khaled F, 2005; and Teixeira *et al*, 2005).

In addition to its chelating action, EDTA has been recommended as an irrigation agent with antimicrobial properties. Almost all manufacturers of nickel-titanium instruments recommend their use as a lubricant during rotary root canal preparation (Hulsmann *et al*, 2003). However caution must be given if the canals are not thoroughly irrigated as some component in the EDTA-urea peroxide-Carbowax mixture was seen to remain in the canal and adversely affect the seal of the root canal filling in a study by Cooke *et al*, (1976). The relevance of this is that EDTA mixture may increase the permeability of the dentin and thus the sealability of the canal may be compromised somewhat.

Torabinejad *et al*, (2003a) investigated the effect of a new solution which contains a mixture of a tetracycline isomer, an acid, and a detergent (MTAD) as a final rinse on the surface of instrumented root canals. The results show that "MTAD is an effective solution for the removal of the smear layer and was found to be more efficient in removing the smear layer than EDTA, and does not significantly change the structure of the dentinal tubules when canals are irrigated with sodium hypochlorite and followed with a final rinse of MTAD".

Von Fraunhofer *et al*, (2000) showed in their study that significantly less microleakage occurred when the smear layer was removed and when the canals were obturated with thermoplasticized gutta-percha. Also canals instrumented with engine-driven NiTi files exhibited less leakage than hand-instrumented canals irrespective of obturation method.

However to contrast the need to remove the smear layer, Ray H and Seltzer S, (1991) showed that removal of the smear layer did not enhance the adhesion of the root filling to the wall of the canal. Froes *et al*, (2000) prepared an in vitro evaluation of four techniques for the obturation of the root canal system in the presence or absence of a smear layer. The results showed "no significant differences in the degree of leakage with and without the smear layer when the samples were considered as a whole. However, when the groups were assessed separately, teeth in the lateral condensation with an accessory main cone group and teeth in the thermoplasticized group leaked less with a smear layer present. In contrast teeth with lateral condensation and a standardized main cone leaked more with a smear layer present. In the vertical condensation groups there was no difference attributable to the smear layer".

In conclusion, clean root canal walls and clean root canal systems is the goal and objective in the preparation. The liberal use of an irrigant and chelator together with correct filing techniques will consistently achieve the necessary environment for bacterial elimination and higher success rates.

Irrigation - Sodium hypochlorite

Cleansing and shaping of the root canal provide for the removal of necrotic tissue and debris as well as reducing the microbial population. As an adjunct to the debridement process, irrigation solutions are used. EDTA mentioned above acts upon the inorganic components of the smear layer, causes the decalcification of peri- and intertubular dentine and leaves the collagen exposed. Subsequently, the use of sodium hypochlorite (NaOCl) dissolves the collagen, leaving the entrances of the dentinal tubules more open and exposed and therefore susceptible to chemical disinfection (Byström A and Sundqvist G, 1985).

The tissue dissolving power of sodium hypochlorite (NaOCl) solutions appears to be strongly dependent on:

1) "the amount of organic matter in the hypochlorite/tissue system
2) the frequency and intensity of mechanical agitation (fluid flow)" (Berutti E and Marini R, 1996)

3) "the available surface area of free or enclosed tissue". (Byström A and Sundqvist G, 1985)

4) Although any concentration of NaOCl between 0.3% and 5% may be used successfully in clinical endodontics, it is stressed that the "mechanical aspects of the technique appear to be more important than the initial hypochlorite concentration" (Moorer WR and Wesselink PR, 1982). Berber *et al*, (2006) showed that especially at higher concentrations (5.25%) NaOCl was able to "disinfect the dentinal tubules, independent of the canal preparation technique used. However 6% NaOCl showed significantly greater zones of inhibition than 3% NaOCl for all endopathogens" (Foley *et al*, 1983; Carson *et al*, 2005; Dunavant *et al*, 2006).

A study by Berutti E and Marini R, (1996) confirms that "sodium hypochlorite does not remove the smear layer, even when used with different temperatures". NaOCl's ability to dissolve collagen tissue is enhanced with an increase in temperature. They also recommended the continued replenishment of the irrigant in order to retain its effectiveness. Their study showed that the "apical portion of the canal was less affected by the irrigant even when the temperature was raised and thus the authors recommended a crown down approach so that the canal that has already been shaped would act as a reservoir for the irrigant and would be available to clean the apical portion better". Other studies showed the addition of chelating agents may help in acting as surfactant which will assist in effecting a deeper cleaning. (Byström A and Sundqvist G, 1985)

Bonsor *et al*, (2006), showed that the "PAD technique was successful in eliminating all the culturable bacteria when the correct combination of photosensitiser and correct energy dose are used and where both the light and the photosensitiser reach the bacteria". The PAD^{tm} system is a photo activated disinfection technique. The principle on which it operates is that photosensitiser molecules attach to the membrane of the bacteria. Irradiation with light at a specific wavelength matched to the peak absorption of the photosensitiser leads to the production of singlet oxygen, which causes the bacteria cell wall to rupture killing the bacteria.

In conclusion, elimination of bacteria from within the root canal system can only be managed with the correct chemical irrigation regime as an important adjunct to the preparation principle of clean dentinal walls for a successful result.

The influence of calcium hydroxide

Histological periapical healing of infected roots obturated in one-step or with prior calcium hydroxide ($Ca(OH)_2$) disinfection was compared by Katebzadeh *et al*, (1999) who found that the "best results were obtained when the infected canals were disinfected with $Ca(OH)_2$ before obturation and thus suggested that its use should be advocated and performed as routine in cases with apical periodontitis". However, Weiger R, Rosendahl and Löst C (2000), found that a one visit treatment of a pulpless tooth was as efficient as a two stage treatment with interim calcium hydroxide appointment from a microbiological perspective and therefore had a similar potential for a healing environment.

Margelos *et al*, (1997), revealed that calcium hydroxide remains at canal walls and apical regions even after an attempt to remove it by standard root canal preparation techniques. Although, the combination of filing, together with 15% EDTA and 2.25% NaOCl treatment demonstrated significantly higher calcium hydroxide removal efficiency. "Probably the EDTA treatment may chelate residual calcium hydroxide, which is then easily removed by NaOCl irrigation. Additionally, treatment with EDTA may neutralise calcium hydroxide residues, but if residues are not removed they may interfere with the sealing efficiency from a mechanical point of view".

The combination of calcium hydroxide and Zinc Eugenol-based sealers (e.g. Roths cement) may block gutta percha placement to full working length. The presence of such remnants at the apical region, may adversely affect the clinical performance of the sealer and possibly the long-term prognosis of root canal therapy. But an in vitro study by Sevimay *et al*, (2004) to examine the coronal leakage of canals medicated with $Ca(OH)_{(2)}$ compared with the canals which did not receive $Ca(OH)_{(2)}$ medication before obturation with laterally condensed gutta-percha points and sealer indicated that the application of $Ca(OH)_{(2)}$ as a temporary dressing material had no effect on coronal leakage.

Sjögren *et al*, (1991), demonstrated that calcium hydroxide was shown to be "highly effective in killing the persisting root canal flora as well as *E. faecalis*, when canals were dressed for 7 days". Even though microorganisms may lie in the complex anatomical variations of the root canal system, such as lateral canals, the continued diffusion of hydroxyl ions will raise the pH sufficiently for the destruction of most or the entire root canal flora.

There are many calcium hydroxide dressings on the market with different mediums in which calcium hydroxide is carried. They may have slow releasing properties or admixtures to keep the calcium hydroxide fresh and potent. There are few studies to back up the promoting literature of a particular brand (Fava LRG and Saunders WP, 1999). However, it was shown that *E. faecalis* was resistant to the application of calcium hydroxide in camphorated paramonochlorophenol medium after 1 hour, but was sensitive to it after 1 day's exposure. In contrast, the calcium hydroxide/saline paste was ineffective against *E. faecalis* and *F. nucleatum* even after 1 week of exposure (Siqueira JF and de Uzeda M, 1996).

The chloroform factor

One of the factors that may have influenced results and specifically the recovery of intracanal bacteria was the use of chloroform. Chloroform toxicity may deprive microbes and in particular that of *E. faecalis,* of their capacity to reproduce (Edgar *et al*, 2006). Thus the use of chloroform may introduce false negative results prejudicing the final bacteria counts (Molander *et al*, 1998). However, Zmener *et al*, (2005) suggest that the study "may have introduced sampling deficiencies due to gutta percha remnants in the canal which may have blocked out sampling fluid from areas where bacteria were present, thus jeopardizing the validity of the sample. Also a leakage risk through the coronal restoration must be taken into account, which could have also invalidated the results".

The periodontal-endodontic and accessory relationship

Sinai IH and Saltanoff W, (1973) as well as Carmen JE and Wallace JA (1994) demonstrated that there is an interrelationship between the periodontium and pulp of a tooth possibly through accessory canals in the floor of the pulp chamber. The second possibility is that an infected tooth or coronal leakage of the final restoration may result in an outward movement of toxins and subsequent periodontal furcation involvement due to the close proximity of the furcation area to the gingival sulcus. Either cause must be investigated and resolved appropriately in order to seal off the patency. The positioning of the rarefaction must be taken into account when the clinician is retreating a failed case. A lateral positioned rarefaction may hint to a wide patent accessory canal. In periodontally induced changes in the pulp, the occurrences appeared to be less frequent and only occur when they involve the root apices (Harrington *et al*, 2000).

Anatomy of the apex

Kuttler Y, (1955); Green D (1956) and De Deus QD, (1975) looked at root tips and found the following facts: "the foramen deviates from the vertex or apical center with increase of age and cementum apposition; the diameter of the foramen increases with age; the minor diameter is usually found in dentin; and it was suggested that root fillings should extend 0,38mm to 0,5mm to the foramen".

Microscopic investigation of root apices by Green EN, (1958) showed that the "majority of fine canals would be adequately debrided by a number ISO 25# file at the apex. The majority of large molar canals would be adequately debrided by a number ISO 35# to ISO 40# file at the apex". The minor diameter at the apex has been described and measured and gives the clinician a starting point to consider which file should most often be considered that would clean the apex. Current files with larger tapers than ISO standard would then clean the canal coronal to this position.

Palmer *et al*, (1971) show how radiographs can be misleading (about 50%) when the apical foramen does not coincide with the anatomical root apex. They suggest that the apical extent and seal is the most common cause of endodontic failure.

Dummer *et al*, (1984), showed that although the "average distance from apex to foramen is 0,38mm, the average distance of apex to apical constriction is 0,89mm". They also presented in their study the four distinct types of apical constriction, as follows: "Type A- the 'traditional' single constriction; Type B- a tapering constriction; Type C- where a number of constrictions were present; and Type D- where the constriction was followed by a narrow, parallel portion of the canal". Their study suggests that there is an important topographical influence when the apex to constriction is considered when taking an accurate working distance measurement. For example, adopting the generally accepted view that the constriction is 1mm from the radiographic apex would suffice in general for constrictions Types A, C and D, but would result in under-preparation of canals with Type B constrictions. On the other hand, purely tactile methods of working distance estimation might produce satisfactory results in constriction Types A, B and D, but would probably result in under-preparation with constriction Type C.

In conclusion, it is important to be able to "visualise" the anatomical design of the apex that is needed to be reached and then cleaned, shaped and filled.

Complex anatomy- accessory and lateral canals

According to Moodnik R and Hempstead NY (1963), nearly all roots have multiple accessory and lateral canals. Endodontic lesions positioned lateral to the root or asymmetrically about the root apex and periodontal sulcular defects of endodontic origin are vivid reminders of the complexity of the root canal system, with its numerous and infinite variety and location of canal ramifications. Endodontic success, however is frequently not impaired by the presence of these lateral and accessory canals, failure can result, though, when these lateral or accessory canals are sufficiently large to permit the egress of tissue-breakdown products that cannot be detoxified or eliminated.

According to Seltzer *et al*, (1967a) and Rubach WC and Mitchell DF (1965), the development of periodontal pockets and bone loss may expose lateral canals located at or near the furcation of molars. Harty et al, (1970) found "inflamed, or necrotic pulp tissue in the accessory canals and contributed the endodontic failure to these unfilled accessory canals".

Pineda F and Kuttler Y (1972) have suggested that the "bucco-lingual plane exhibits more diversity in the root canal anatomy than when commonly seen in the mesio-distal plane". They found in their in-vitro investigation of 7275 root canals that "33% of the roots were narrow and markedly curved. 30.6% of teeth had ramifications (accessory or lateral canals) of the main root canal and was most commonly found in the apical third". A study by De Deus QD, (1975) showed that 27.4% had accessory canals. The maxillary central incisors had more ramifications (11.9%) in the middle third of the root and maxillary premolars had more (55.2%) in their apical third. In a scanning electron microscopic study, it was found that the frequency of accessory foramina involving both the pulp chamber floor and the surface of the furcation ranged from 48% in maxillary molars to 56% in mandibular teeth. If these accessory canals are overlooked and are insufficiently sealed, the prognosis for successful treatment may be reduced. This is particularly important in cases where there is periodontal disease involving the furcation. (Swanson K and Madison S, 1987; Saunders WP and Saunders EM, 1990)

Slowly R (1974 and 1979) in his study of x-rays has pointed out the clues in finding "extra" canals in teeth. All roots may have extra canals, however they are most commonly found in the mesio-buccal root of the maxillary first molar and the distal root of the mandibular molars. Radiolucent lesions positioned to the side of the root may indicate an existence of a lateral canal, or lesions associated with a radiographical "successful" obturation may indicate accessory or lateral canals un-located and unfilled.

The variations in root canal ramifications within teeth are described by different authors (Miyashita *et al*, 1997; Karagöz-Küçükay I, 1994) may be due to the dissimilarity in the terminology used to identify the root canal ramifications, the techniques used, the age of the patients tooth, or the clinical diagnosis of the teeth indicated for extraction. It is generally agreed that with advancing in age the canals may become sclerosed due to dentine or cementum deposition. The patency or enlargement of the accessory or lateral canals may be due to a resorption process while in an area of inflammation in the pulp or adjacent tissue. Miyashita *et al*, (1997) agree that "the incidence and thickness of lateral branches and the number of apical ramifications appear to play a role in the onset of radicular lesions".

In conclusion, it is clear from the literature that the prevalence of lateral and accessory canals is significant in number. Many root canal therapies are successful, however, without the clear or full obturation of main canals, or even the demonstration of accessory canals. The prognosis of these "successful" root treatments may be in question, as the currently, symptom-free tooth, may later flare up.

Radiolucent lesions may exist with quiescent subacute periodontal reactions and subsequent bony alterations. Persistent periodontal pocketing may be attributed to these unfilled accessory canals. Failure of retrograde fillings from apicoectomy procedures could also now be linked to these unobturated and percolating canals. The possibility exists for their obturation when the main canals are cleaned, irrigated well and shaped correctly. The obturation methods, be it lateral or vertical condensation, both may provide for their obturation when executed correctly. Once the accessory or lateral canals are demonstrated, it provides satisfaction to the clinician, as the root canal has surely been obturated in all three dimensions and a successful root treatment is confirmed. (Zolty G, 2001)

Technical standard of the seal in obturation

Supportive clinical data have been presented showing that the development of periapical radiolucencies after retreatment is significantly associated with overinstrumentation and overfilling of the root canal. Root filling material used must therefore adversely affect the periapical tissues either by retarding or by preventing their healing (Seltzer *et al*, 1963; Bergenholtz *et al*, 1979).
Thus it is axiomatic that the success of root canal therapy therefore depends on the technical standard of the root filling. It would thus be consistent to provide a tightly filled canal without voids up to the apical constriction. Therefore gaps not always detectable in radiographs between the root filling and the root canal wall are potential sites for reinfections, which may harm the periapical area. A higher frequency of remaining or additional periapical lesions was observed in which no cleaning through the apex took place or it may be due to the canal not been cleaned and infected dentin sediment not removed from the apical area. (Bergenholtz *et al*, 1979).

In the study by Ridell *et al*, (2006) the technical quality of obturation was related to the periapical status at follow-up. The results showed that "apical periodontitis was found in 52% of the teeth, significantly more often among molars than among anterior teeth". However they also found that over half of the teeth studied were inadequately sealed. In only 38%, the distance to the apex was <2 mm and overfilling was registered in 14% of the teeth.

Teeth without alteration of root canal morphology and without pre-existing periapical lesions had a higher success rate than teeth with altered morphology and with periapical lesions following retreatment (Stoll, *et al*, 2005).

In conclusion, the technical standard of obturation is only the "visual" outline of the completed and "filled" root canal. It is axiomatic that obturation follows preparation. The studies only describe the completed case and give commentary for the results and do not take into account the technical standard of preparation of the canals that lead up to the standard of the "fill".

Sealability of cements

Grossman LI, (1982) elucidated eleven requirements and characteristics of a good root canal sealant. To date many sealants produced, may prove positive in some aspects, but not all. The literature is replete with evaluations of their sealing effectiveness, many of them contradictory, and virtually all questionable as to their validity.

A series of test procedures were developed for the purpose of investigating the relative physical properties of a group of commercial root canal sealing agents. Common cements used are Tubliseal, Kerr's pulp canal sealant, AH-plus etc. and thus it would be correct to review literature that had studies comparing their leakage potential.

It was noted that the solubility of Tubli-seal was relatively increased when stored in acetic acid. Therefore noting that, as an apical infection or abscess provides an acidic environment, this may have a detrimental effect on the seal of Tubliseal (Higginbotham TL, 1967). In a study by Cooke *et al*, (1976) it was shown that "EDTA might remain in the root canal even after thoroughly cleaning and this may potentially have an affect on the sealant agent". Kerr's Pulp Canal sealant demonstrated better sealing after 1 month than after 1 day.

When preparing a post space this seal may be disturbed, depending on the time interval after obturation. Marshall FJ and Massler M (1961), and Kapsimalis *et al*, (1966), studied the sealing properties of a number of commercial sealants using radioactive isotopes of different particle sizes and chemical polarity. They found that the use of S^{35} was the most practical for these tests because of the excellent detail and deep penetration which it showed in the autograms. Of the eight root canal cements in Kapsimalis *et al*, (1966) study, Proco-sol and AH-26 showed no leakage. Kerr's pulp canal sealant in this study showed leakage amongst the others. They also suggest that "the skill of the operator is perhaps more important to successful obturation than the materials used".

Hovland EJ and Dumsha TC, (1985), compared the sealibility of Sealapex, Tubliseal and Procosol. They found that they all leaked to some extent, but there was no difference between them. They demonstrated that leakage mainly occurred at the interface of material and dentine. Some teeth leaked between the solid core of gutta percha and the cement. Most leakage occurred within the first 24 hours. A further study by Khademi *et al*, (2004) compared the coronal leakage of root canals obturated with five root canal sealers using *E. faecalis* as a microbial tracer. Under the conditions of their study, none of the sealers tested could predictably produce a coronal bacterial seal of the root canal against the ingress of *E. faecalis*, although Roekoseal Automix performed significantly better than the rest. Kopper *et al*, (2003) compared the sealing ability of the endodontic sealers AH Plus, Sealer 26 and Endofill (Dentsply, Industria e Comercio Ltda.) in premolar teeth of dogs exposed to the oral cavity after post-preparation. They found that the extent of dye penetration (statistically significant) for AH Plus was least followed by Endofill and then Sealer 26. They also confirmed that after 45 days exposure to the oral cavity, none of the sealers was capable of preventing leakage and coronal dye penetration. In conclusion, it appears that different sealants may have an effect on the microleakage.

A study was made to compare the effect of different obturation methods in the control of microleakage (De Moor RJ and De Bruyne MA, 2004). The study included AH 26 and AH Plus in conjunction with three different obturation techniques (lateral condensation and hybrid condensation of gutta percha or obturation with Thermafil). They found that there were no statistically significant differences in apical leakage within the AH 26 and the AH Plus groups, nor between the two sealer groups, at any observation period. Coronal leakage was significantly higher for Thermafil obturation compared to the other obturation techniques. So it can be concluded that AH cements were similar in controlling microleakage irrelevant to the obturation technique performed but Thermafill obturation was the weakest.

Trope M and Ray HL, (1992), showed that teeth roots were significantly weakened when the root canals were instrumented. The roots of canals obturated with gutta percha cones and glass ionomer sealers were significantly stronger than roots where canals were instrumented but not obturated and those obturated with gutta percha cones and Roths 801 sealer. Ray H and Seltzer S, (1991), in their study compared a new glass ionomer to Grossman's root canal sealer, and they found that "the glass ionomer chemically bonded to the dentin of the root canal". Such bonding they posit would "confer a distinct advantage in endodontic therapy, preventing percolation and bacterial penetration at the sealer-dentin interface". In this study, removal of the smear layer did not enhance adhesion. Saunders *et al*, (1992b), also came to similar conclusions regarding the adhesion of the cement, except in their study they showed that removal of the smear layer with citric acid definitely improved the adhesion of the glass ionomer to the dentin wall.

Newer obturating materials have come onto the markets which have been proposed to bond to the dentine of the canal walls and thereby produce a "monobloc" of synthetic polymer gutta percha together with the dentine wall and thus reduce microleakage. One such material is Resilon with Epiphany sealant material. Shipper *et al*, (2004) showed that Resilon showed minimal leakage, which was significantly less than standard gutta-percha, in which approximately 80% of specimens, sealed with either lateral or vertical condensation technique or sealer, leaked. A further test by Tunga U and Bodrumlu E, (2006) confirmed this with similar results. The teeth filled with gutta-percha and AH 26 displayed the most apical leakage. The least apical leakage was shown with Resilon.

Ungor *et al*, (2006) showed that the bond strength of resin-based Epiphany-Resilon root canal filling system was greater than when comparing against different pairings of AH Plus and gutta-percha. The authors found that the Epiphany-Resilon combination was not superior to that of the AH Plus-gutta percha combination. They posit that the bond strength should be an indication of the microleakage control.

In contrast, a study by Stratton *et al*, (2006) was to compare the sealing ability of gutta-percha and AH Plus sealer versus Resilon and Epiphany Resin Root Canal sealer. The results showed that the group using Resilon with Epiphany sealer had significantly less leakage when compared to gutta-percha and AH Plus sealer. However in later studies it was found that the AH Plus and Gutta Percha verse Resilon/Epiphany did not show any advantage and had similar results for leakage (Fransen J, *et al*, 2008).

It appears that new sealants on the market may become the benchmark for the use and comparison of leakage with regard to their adhesion abilities. The development in this area may provide for even further improvement and statistically significant results. The difficulties in a clinical setting for these kinds of adhesive sealants are due to the wet canal environment which may compromise the adhesion. This is particularly sensitive in the apical region which is naturally bathed in fluid.

Multi-factors

It is important when investigating the cause of root canal failure to look for the principle reason for root canal failure such as untreated canals and coronal leakage. Often factors associated with root canal treatment failures are multivariate (Hoen MM and Pink FE, 2002).

Strindberg LZ, (1956), found that a 4-year control period after completion was the earliest on which results could be based. Strindberg found that the factors that had a significant effect on the treatment results were:

1) "Number of roots per tooth.
2) The pulp status. Roots with vital pulp had higher failure rates. Previous root treatment did not change prognosis. These results became evident at greater than 4 years post treatment. However it is known that non-vital pulps are often infected and later research found non-vital to have poorer resolutions (Kojima *et al*, (2004).
3) Periradicular status. The failure frequency was greater for cases with periradicular rarefactions than in cases without periradicular rarefactions at the time of treatment.
4) Class of root filling. Roots with great excess of root filling material had a higher failure frequency than those with no, or little, excess filling material. Roots with canals which could be instrumented through the apex had a higher failure frequency than those which could not be filed through the apex. This was found in both roots with vital and non-vital pulps. The prospects of successful treatment appeared to be diminished when the teeth were affected by apical resorption. Apical resorption was found in the case of roots with and without periapical rarefaction, and in vital as well as non-vital pulps".

Sjögren *et al*, (1990) evaluated the success or failure of root treatments and found that they were directly dependant upon the preoperative status of the pulp and periapical tissues. The rate of success for cases with vital or non-vital pulps but having no periapical radiolucency exceeded 96%, whereas only 86% of the cases with pulp necrosis and periapical radiolucency showed apical healing. Teeth with necrotic pulps and periapical lesions that had their entire root canal instrumented to their full length and level of root filling was optimally positioned to within 2mm of their apices, were those that showed positive outcome. Of all teeth with periapical lesions present on previously root filled teeth, only 62% healed after retreatment. It appeared that the level of root filling did not influence the healing in these retreated cases. The best prognosis was when the root filling finished within 2mm of the apex. The preoperative size of the periapical lesion did not influence the outcome in treatment with necrotic pulps when treated for the first time, but there was an improvement in retreated cases with lesions of less than 5mm in diameter. It appears that rarefactions with ill-defined borders as opposed to well defined lesions do not have a clear bearing on the prognosis.

The prognosis was reduced for teeth with preoperative pulp necrosis and periapical lesions when the root was restored with a crown or acted as an abutment for a bridge. There was no change in prognosis in retreatment cases. Factors such as "age, sex of the patient, presence of deep periodontal pockets, whether the roots were provided with posts or not or were used as abutments for partial dentures, and the number of bacterial sampling done before filling the root had no influence on the outcome of the treatment". These factors did not influence the results for retreatment cases. Neither a flare-up occurring during treatment nor the presence of an initial acute periapical abscess influenced the result of treatment.

Matsumoto *et al*, (1987), Storms JL, (1969) and Lin *et al*, (1992) investigated the correlation between prognosis and various factors such as, bacteriological examination, rarefactions, root canal filling classes, periodontal pockets, clasping teeth, occlusal trauma, and the presence of adjacent teeth that would possibly influence the prognosis following root treatment. The results demonstrated that there was "no difference between the success and failures of teeth with regard to their bacteriological cultures at time of filling" (confirming Seltzer *et al*, (1967a) study, but contrary to Engström *et al*, (1964). There was "a decrease in success when a tooth had a pretreatment rarefaction associated" (confirming Seltzer *et al*, 1967a) study. Their study also confirmed that a higher success rate was obtained when the root filling was underextended rather than overextended. Their results showed that "there is a direct relationship between a deep periodontal pocket or occlusal trauma and treatment failure in endodontics". Their study showed a higher incidence of failure when the tooth was an isolated tooth or had only one adjacent tooth (confirming Sjögren *et al*, 1990).

Seltzer *et al*, Part I (1967a) found that treatment failures occurred equally in both sexes. The largest number of failures occurred in patients aged 31 to 60 years. Failures occurred twice as frequently in upper anterior teeth than lower and least in molars. In lower teeth, the first molar failed most frequently; the fewest failures were found in cuspids. Their findings also indicated that teeth with pretreatment areas of rarefaction are more likely to fail following endodontic treatment by a ratio of 2½ to 1. Most endodontic treatment failed within a 24 month period. They noticed that in teeth, in which endodontic treatment failed, inflamed or necrotic pulp tissue was discovered in accessory canals. They found that a majority of teeth that failed also were associated with defective coronal restorations. The rest of the teeth failed due to fractures of root, caries, broken instruments in root canal, perforations of floor of pulp chamber or root and calcified canals (or non-negotiated canals). They noted that teeth associated with periodontal disease resulted in an increase in number that had failed treatment. The influence of periodontal disease is greater when associated with posterior teeth. More failures occurred in endodontically treated teeth that were crowned or that acted as bridge abutments than in teeth not so involved. This tendency toward increased incidence of failure in crowned teeth was seen especially in posterior teeth with periodontal involvement. Thus there was an indication that traumatic occlusion might have contributed to the failure frequency. Cysts were associated with endodontic failures in the majority of cases. According to Seltzer *et al*, Part II (1967b) they could not give a reasonable explanation for the lack of healing, following nonsurgical treatment, of the periapical lesions which was granulomatous. Apparently, “granulomatous lesions may persist for years without symptoms and without complete repair”.

In conclusion, the above studies showed that most failures were affected by multiple factors.

Coronal seal and bacteriological leakage

Coronal microleakage is one of the primary causes of endodontic failures (Torabinejad *et al*, 1990; Madison S and Wilcox LR, 1988; Saunders WP and Saunders EM, 1994), and can often be related to the quality of the seal established with the restorative material after endodontic obturation (Chailertvanitkul *et al*, 1997). The purpose of a study by Ray HL and Trope M, (1995), was to "evaluate the relationship of the quality of the coronal restoration and of the root canal obturation on the radiographic periapical status of endodontically treated teeth". They found that teeth with tightly sealing coronal restorations had a higher success rate (80%) with an absence of periapical periodontitis than those teeth which had well-obturated root canals (75.7%). Poor coronal restorations resulted in significantly more teeth with periapical periodontitis (48.6%), than teeth which had poor root fillings (30.2%). The combination of good coronal restorations and good root fillings had the highest score for healed periapical periodontitis of the order of 91.4%; whereas teeth with poor coronal restorations in combination with poor root fillings had18.1% healing. This was statistically significant.

The results demonstrate that emphasis must be placed on providing a good non-leaking coronal restoration as a means to securing the prognosis of endodontic treatment. Clearly the current obturation techniques do not accomplish the main stated criteria of obturation, which is to hermetically seal the root canal space. An impervious seal may be created at the orifice after the root canal is filled or the coronal restoration should be extended apically with a view to sealing off the root canal system. The present review has also advocated the extension of the coronal seal to the canal space when placing a post under a sterile environment, such as a rubber dam.

The same subject was investigated by Siqueira Jr. *et al*, (2005). Data analysis revealed that when the root canal filling appeared to be adequate, the quality of the restoration did not significantly influence the treatment outcome. However, when a coronal restoration was absent, the success rate of adequately treated canals was significantly reduced. The quality of the coronal restoration significantly affected the outcome of inadequately treated teeth.

Machtou P, (2004), reviewed studies on the subject of the importance of coronal seal. The author also brought research to support the fact that good coronal seals with poor root fillings may prejudice success. So it appears that health of the periodontium is directly related to their coronal seal and good root filling. It was also mentioned that it was important to leave at least 3mm of gutta percha below a post in order to retain an apical seal. It appears that research is directed towards obtaining newer obturating materials that retain the "same qualities of gutta percha but add an ability to seal the prepared canal with "monobloc" obturation hence creating a continuum with the coronal restoration".

Sealed root canals can be recontaminated under several circumstances: (a) if the patient has had endodontic treatment but has delayed placement of a permanent restoration; (b) if the seal of the temporary filling material has broken down; or (c) if filling materials and/or tooth structures have fractured or been lost. When these situations occur, the coronal portion of the root canal system is exposed to oral flora. The question is how quickly the entire root canal system becomes contaminated again, to the point that retreatment of the canal may be necessary.

Torabinejad *et al*, (1990) showed that 50% of the root canals were completely contaminated after 19-day exposure to *S. epidermis* and after 42 days to *P. vulgaris*. However, Wu *et al*, (1993), demonstrated that only after 50 days exposure to *P. aeruginosa*, only 7% of the filled canals allowed passage of this bacterium. A similar test was made where the teeth were incubated in human saliva (Khayat *et al*, 1993). They compared the leakage interval from lateral and vertically condensed fillings. They found that the "teeth were contaminated within 30 days and that there was no statistically significant difference between the methods of obturation be it lateral or vertical compaction".

In a study by Swanson K and Madison S, (1987), to determine coronal microleakage by dye take-up in obturated teeth specimens, the leakage was seen after only 3 days exposure to artificial saliva. The authors suggest that "the permeability of sealants to oral fluids should be a consideration when selecting a sealer for clinical use". However in a later study by Madison S and Wilcox LR, (1988), showed that although different sealers allowed dye penetration at different and variable levels, there was no statistically significant difference. It appears in the literature that there is not one sealant that does not allow some leakage so the conclusions drawn from this study are relevant to direct our attention to another cause of root canal failure. These studies confirm that coronal microleakage should be considered as a potential etiological factor for root canal failure and thus the final coronal restoration should be prepared as soon as possible following root treatment. The frequency of accessory foramina involving both the pulp chamber floor and the surface of the furcation ranged from 48% in maxillary molars to 56% in mandibular teeth. If these accessory canals are overlooked and are insufficiently sealed, the prognosis for successful treatment may be reduced. This is particularly important in cases where there is periodontal disease involving the furcation (Alves *et al,* 1998; Swanson K and Madison S, 1987; Saunders WP and Saunders EM, 1990).

Magura *et al*, (1991) suggests that a thickness of greater than 3mm of IRM should be used or the clinician should use a double seal of grey Cavit and IRM in order to prevent ingress of salivary fluid. However, Barthel *et al*, (1999) investigated the ability of different coronal temporary fillings to prevent coronal-apical penetration of bacteria and found that the Cavit group, the IRM group, and the Cavit/glass-ionomer cement group showed significantly more leakage than the glass-ionomer cement group of the IRM/glass-ionomer cement group. This in vitro study seemed to indicate that "only glass-ionomer cement and IRM combined with glass-ionomer cement may prevent bacterial penetration to the periapex of root-filled teeth over a 1-month period".

Carmen JE and JA Wallace, (1994), demonstrated that all coronal restorative materials tested did not prevent microleakage. There was no statistically significant difference between the mean leakage for the amalgam and light-cured glass ionomer groups, but the mean leakage for these two groups was significantly lower than that of core paste, light-cured composite and IRM groups.

A further study by Seiler KB, (2006) compared five restorative materials used to coronally seal endodontically treated teeth against bacterial leakage. The results of this in vitro study indicate that glass ionomer and resin-modified glass ionomer restorative materials provide a better coronal seal against *Streptococcus mutans* than zinc oxide/eugenol in endodontic access cavities.

Howdle *et al*, (2002), concluded from their study that in order to prevent the reinfection of the endodontically treated molar it may be preferable to restore the tooth immediately after obturation by employing a bonded amalgam coronal-radicular (Nayyar) technique as compared with conventional amalgam restorations since they tested less leakage. Their study indicated that any adhesive agent produced better results and may include the use of Vitrebond (Al-Moayad *et al*, 1993).

The 'ferrule effect' in post-endodontic restoration

The study by Sorenson JA and Engelman MJ, (1990), demonstrated that it was not "the contrabevel or metal collar of the cast core, but the resistance form of the artificial crown against the residual coronal dentin that is crucial in the design". The ferrule is provided by parallel walls of dentin coronal to the shoulder of the preparation that elevates resistance form. A modification of the definition of the "ferrule effect" is suggested. The ferrule effect is a "360-degree metal collar of the crown surrounding the parallel walls of the dentin extending coronal to the shoulder of the preparation". The result is an elevation in resistance form of the crown from the extension of dentinal tooth structure. The critical design in endodontically restored teeth is the support of the crown against the reciprocating walls of residual dentin coronal to the shoulder. The authors showed that in order to achieve the minimum amount of resistance form the collar would need to be at least 1mm high. Factors contributing to a poor prognosis are (1) lack of coronal tooth structure, (2) poor crown-root ratio, and (3) inadequate root length for extrusion.

Whenever possible, the preservation of the coronal portion of the tooth must be maintained as much as possible during the restoration of pulpless teeth and as such inlays and onlays, as alternatives to full crowns must be considered. Adhesive techniques of posts and cores may improve water tightness of the dental structure and contribute to improved retention. A radicular post is not always necessary in those cases with an adequate ferrule present. This also contributes to the preservation of the dental structures while delivering a biocompatible and aesthetic restoration (Castany *et al*, 2003).

Yang *et al*, (2001) showed that different angles (to the horizontal) of loading pressure on teeth would produce "corresponding increasing stresses". It was noted that the dowel and core provided little reinforcement to the remaining tooth. Parallel-sided dowel and cores with a length of 12 mm distributed the stress widely in the restoration and dentin, resulting in the smallest stresses.

Zhi-Yue L and Yu-Xing Z, (2003) investigated the effects of post-core design and ferrule on the fracture resistance of endodontically treated teeth. They found that not all of the post-core structures tested improved the strength of the endodontically treated teeth. Those prepared with a 2-mm dentin ferrule more effectively enhanced the fracture strength of custom cast post-core restored endodontically treated maxillary central incisors.

In conclusion, it is more advantageous to rely on the ferrule than on a post to support and retain a crown and thereby ensure a coronal seal.

Post-endodontic restoration: post placement

Neagley RL, (1969); Zmener SO, (1980); Portell *et al*, (1982); Raiden GC and Gendelman H, (1994) and Wu *et al*, (1998) demonstrated the effect of immediate verse delayed dowel preparation on the integrity of the apical seal was dependent upon the length of remaining gutta percha in the canal of the root at the apex. They found that the most microleakage occurred from the delayed preparation if only 3-4mm of apical gutta percha remained. Conversely, the least incidence and degree of microleakage were shown in the group in which immediate preparation of dowel was performed leaving 7mm of apical fill. These findings may be of clinical importance when restoring short roots. The effect from time between obturation and dowel space preparation leaving 7mm of apical fill was not statistically significant (Bourgeois RS and Lemon RR, 1981). However it was evident that there would be a better seal from immediate preparation of the dowel space following obturation.

Southard DW, (1999), strongly advises against shaping the canal to fit a prefabricated post, rather the post is modified to passively fit the canal. The author advocates that Gates Glidden drills are used to prepare the post space. In this way the incidence of perforation of the canal is reduced.

Various cross-sectional studies have noted apical lesions in 41-67% of teeth restored with posts. It is argued whether clinicians prepare a post space under "sterile" conditions, such as rubber dam or "clean" the prepared post space with sodium hypochlorite. Unless those steps are performed, however, we may be introducing bacteria directly to the apical portion. Also since temporary post crowns do not provide a good coronal seal it would appear that, when a post is required a "better option would be to definitively cement a prefrabricated post after obturation" (Youngson C, 2005; and Ricketts *et al*, 2005). In fact, it is more advantageous to place an immediate core at the time of the endodontic obturation (Swanson K and Madison S, 1987; Saunders WP and Saunders EM, 1990). Considering the coronal canal and pulp chamber spaces as integral components of the endodontic treatment compels the clinician to control these spaces and expand the "endodontic seal" to the cavosurface margins under rubber dam isolation. In this manner, the immediate build-up becomes an extension, rather than an invasion, of the endodontic seal and may even increase the success rate of endodontic therapy.

As a result of aesthetic developments and the increased requirements of the rehabilitation of post-endodontic teeth, translucency and natural optical characteristics have assumed increased importance in the cervical and radicular space. There are limitless possibilities in dowel and core rehabilitation with transilluminating posts, bondable fabric, and high-technology ceramics. The key to proper selection of an aesthetic and practical post system is thorough understanding of dentine behaviour and the adhesive qualities that are presented in the various systems. The current research has allowed new post technologies to "unify morphology and structure for aesthetic objectives" (Gluskin *et al*, 2002).

Drummond JL (2000); Stewardson DA, (2001) and Ferrari *et al*, (2001a) have reviewed non-metal post systems currently on the market. The authors have described the function of posts being used for the retention of core fillings. Historically, metal posts have been used and their advantages were of their adaptability of canals as well as angulations of root to crowns. Cast metals have greater strength in thin section than the composite adjacent to fibre posts. This allows the production of ferrules. The disadvantages of metal posts are that they are rigid and introduce root fractures when stressed. Metal posts are unaesthetic and are not biocompatible and may cause discolouration of the root due to corrosion products. Metal posts are more difficult to remove when necessary to endodontically retreat the tooth.

Metal-free alternatives currently available can be broadly divided into either composite materials or ceramics. Composite materials are composed of fibres of carbon or silica surrounded by a matrix of polymer resin, usually an epoxy resin. The philosophy behind the use of these materials lies in the belief that a post should mimic the dentine of the root in its physical properties, distribute the stresses imposed on the restored tooth in a more favourable way and thereby reduce the incidence of root fracture. While it may be beneficial for the post to match the flexural modulus of the dentine, it would appear to be equally important for the luting material at the interface of these materials to be able to flex harmoniously. There are plethora of fibre posts on the market with research to back up their biocompatibility, improved aesthetics in the critical smiling zone, as well as strength, performance and longevity of these types of posts and microleakage and also ease of retrieval (Dean *et al*, 1998; Fredriksson *et al*, 1998; Cornier *et al*, 2001; Mannocci *et al*, 1999; Duret *et al*, 1991; Ferrari *et al*, 2000a; Ferrari 2001a; Ferrari *et al*, 2000b; de Rijk WJ, 2000; Usumez *et al*, 2004).

A study by Ferrari *et al*, (2001b) showed that a dual-cure self-activating system showed a "more uniform resin tag and resin-dentin interdiffusion zone formation" along root canal walls than light-curing systems and thus this would indicate a lower microleakage score and decreased chance of debonding and breakdown of the endodontic and coronal seal. In fact it has been shown that the liberal use on NaOCl during endodontic treatment may cause an enhanced bonding strength when the posts are bonded with the use of dentine adhesive primer. In a study it was found that there was no significant difference between Panavia 21 Ex and Duel Cement. (Varela *et al*, 2003)

In conclusion, the ever advancing science of dental materials has an important role in the post-endodontic restoration. The advantages of the bondable glass fibre posts over the cementable semi- precious gold posts are the ability to immediately seal the coronal portion of the tooth in the same appointment with the fibre posts. When necessary, there is greater ease to retreat the tooth since it is easier to remove the fibre post to get to the canal portion. The use of the tooth coloured fibre posts may be relevant in the aesthetic zone, as compared to the semi-precious posts which may cast a "shadow" in the crown.

Knowledge required for re-access and disassembly prior to retreatment

Rosenberg D (2003a), described multiple ways to negotiate to the apex following iatrogenic obstructions that hinder progress to the apex. He describes the use of greater taper files that efficiently remove ledges. The author debates the issue that it is impossible to clean the root canal system, but merely to shape it. The files and filing are used primarily to deliver the irrigants throughout the root canal system. He argues that we rely on the irrigant to clean the root canal system (Rosenberg D, 2003b). Today, with the surgical operating microscope and improved lighting and vision that it provides, it is rare that calcified canals cannot be located and accessed (Castellucci A, 2003; Niemczyk SP, 2003). Once the occluded coronal portion of the canal is accessed, instrumentation to the apex can be completed.

The removal or disassembly of post and cores often act as a deterrent in advising endodontic retreatment when faced with a failed root filling under a post-supported crown. This should not be the case as there are easy and straight forward approaches for their atraumatic removal (Glick DH and Frank AL, 1986; Machtou *et al*, 2001). Well adapted posts require greater tensile force to break cement seal and liberate the post. A well fitting post, with minimal cement film thickness contributes to retention of the post. On the other hand posts in asymmetric or ovoid root canals are usually not well adapted to the buccal and lingual walls as a result of which a thick layer of cement is usually found in these areas. In addition, the density of cement usually decreases progressively towards the apex. This not only results in reduced retention but also offers the clinician a unique opportunity to advance a number 10 or 15 K-file alongside the post and with circumferential push-pull motion of the file remove the cement around the post in order to liberate the post (Iqbal M and Karabucak B, 2002).

Suter *et al*, (2005) showed that in their study that 87% of separated files in root canals were removed successfully. They noted more fractured files in curved roots and that rotary files separated more often than hand files. Half of all instrument fractures occurred in mesial roots of lower molars and most often when using rotating instruments. They did not find the location of the separated file to have any effect on the chance of removal when using an operating microscope and suggested that its use was a prerequisite for the successful removal of the fractured instruments.

Cleaning and shaping

Cleaning and shaping of the root canal system is a primary objective of root canal therapy (Schilder H, 1974). He stated that "the objectives of making the final root canal preparation conform to the general shape and spatial relationship of the original canal may be the most neglected phase of endodontic treatment and that the greatest problems lie in attempting to maintain the canal curvatures in the apical regions". Weine *et al*, (1975), demonstrated that every file, whether precurved or not, tended to straighten a curved canal. They concluded that despite instrument selection or technique used, prepared canals showed undesirable changes in root canal morphology that reflected the inability to maintain the original direction and shape of the canal (Murphy R and Tracy N (1969); Di Lenardo *et al*, 2004). A multitude of techniques for hand instrumentation of curved canals have been advocated in an attempt to address these problems (Abou-Rass *et al*, 1980; Goreig *et al*, 1982; Fava LRG, 1983; Roane *et al*, 1985; Saunders WP and Saunders EM, 1992a; Buchanan LS, 1989).

The canal preparation procedure can be quite time consuming and tedious. Factors that can make instrumentation more difficult include tooth length, degree of canal curvature and canal diameter. The problems encountered when using rotary instruments in curved canals are identical to those associated with hand, sonic and ultrasonic instruments in curved canals. These include ledging into the canal wall dentin, stripping of the lateral wall, perforation of the root into the periodontal ligament, zipping of the apical foramen and instrument separation (Abou-Rass *et al*, 1980; ElDeeb M and Boraas J, 1985; Weine FS, 1998). There are procedures or differing techniques which may give more tactile sensation of the apex and thus greater control in the all important apex zone, which may help improve and manage complex canal anatomy (Stabholz *et al*, 1995).

Recent advances in technology have permitted the manufacture of endodontic files from Nickel-Titanium alloy with a very low modulus of elasticity. They have a superior resistance to torsional fracture when compared to stainless steel files. The flexibility of endodontic files is an important characteristic as the more flexible files tend to negotiate curved canals better and reduce the tendency of straightening, zipping, ledging or perforation of curved canals (Mullaney TP, 1979).

Nickel-Titanium hand and engine-driven files maintained the original canal path when tested in fine curved canals as compared with stainless steel files. The incidence of deviation from the original canal path during instrumentation with stainless steel files increased with file size. The difference between Ni-Ti groups and stainless steel files became statistically significant with instruments larger than file size 30. Ni-Ti files were more effective and quicker in maintaining the original canal path of curved root canals when the apical preparation was enlarged beyond size 30 (Esposito PT and Cunningham CJ, 1995; Glosson *et al*, 1995; Ruddle CJ, 2001b; Schrader *et al*, 1999).

The market is replete with a number of file systems that are available to the clinicians. They are promoted to have one advantage over the other and are competing for the marketing edge in price, ease of use and branding. (Baumann MA, 2003a and 2003b). The file systems may include: RaCe, K3, ProTaper, Profile, Hero, TriNitri, to name a few.

3-D Obturation

Overall, the high percentage of gutta percha, minimal amount of sealer and relative absence of voids suggest that the System B may produce an acceptable root filling (Ruddle CJ, 1992; Silver *et al*, 1999 and Buchanan LS, 2004).

Single or multiple appointment treatment

We have discussed earlier (see page 9) in this review the advantages of more than one treatment appointment in reducing the quantity of microorganism infection and the increased ability of cleaning and shaping the canal to an optimum. A number of studies have been done to determine the incidence of post-operative pain after single and multiple-visit endodontic procedures (Roane *et al*, 1983; Walton R and Fouad A, 1992). The studies found in favour of one or the other, but it appears that the number of appointments do not overall cause more flare-ups (Fava LRG, 1989). In fact the post-operative healing is unaffected by number of visits (Ferranti P, 1959; and Soltanoff W, 1978). Whether a tooth pulp was vital or not had little effect on postoperative pain. However, teeth without radiolucent apical areas appeared to be associated with more postoperative pain than those with apical radiolucency (Fox *et al*, 1970). Walton R and Fouad A, (1992) found that complete debridement of canals of necrotic pulps (and presumably with bacteria also) did not prevent or even have an effect on the incidence of flare-ups. This is contrary to earlier studies (Seltzer S and Naidorf IJ, 1985a). In fact, the number of flare-ups in the partial versus the complete preparation groups was nearly equal. Logically it would be desirable to remove intracanal irritants as a preventative measure but apparently this is not the case.

Lately, Eleazer PD and Eleazer KR, (1998) compared one-visit versus two-visit endodontic treatment. Sixteen flare-ups (8%) occurred in the two-visit group versus six flare-ups (3%) for the one-visit group. This showed an advantage for one-visit treatment at a 95% confidence level. In a second comparison, one-visit patients who had previously received two-visit treatment for a different non-vital tooth served as their own control, there were no significant differences in number of flare ups, meaning that there was no advantage of two-visit root canal treatment. However, according to the findings by Trope M, (1991), teeth without apical periodontitis did not flare-up and may be treated in a single visit. Teeth with apical periodontitis, but no previous root treatment can be treated in a single visit, with a low probability of a flare-up occurring; and teeth with apical periodontitis which need retreatment, the flare-up rate was highest and single visit root treatment would be inadvisable (Seltzer S and NaidorfIJ, 1985a and 1985b).

Retreatment

What does retreatment mean? Non-surgical retreatment is an endodontic procedure used to remove materials from the root canal space and, if present, address deficiencies or repair defects that are pathologic or iatrogenic in origin. The disassembly of the post-crown and root canal corrective procedures then allow the clinician to 3-D clean, shape, and pack the root canal system (Flemming PS, 2003).

The difficulty we are faced when retreating a failed case is correcting or repairing damage left from a previous failed root treatment (Seltzer S and Naidorf IJ, 1985; Gorni FG and Gagliani MM, 2004; and Stoll R, *et al*, 2005).

Results were compared of retreatment cases between two clinical representative groups; one with modified anatomy from previous endodontic treatment and the other with teeth in which no significant anatomical changes were made by former endodontic treatment. The overall success rate in the study by Gorni FG and Gagliani MM, (2004) was 69.03%; the success in the root-canal-morphology-respected group was 86.8% and in the root-canal-morphology-altered group 47%. Therefore it appears that teeth that have iatrogenic morphological altered root canals following initial failing root treatment will statistically produce a decrease in potential for the successful outcome of retreatment cases.

It is clear that there are many reasons why retreatment offers a decreased success rate. The current study will try to identify those factors that may have an influence on the prognosis following retreatment.

Chapter 2

The Aim of the Study

The aim of the current clinical study was to identify factors that may influence results following non-surgical retreatment. A number of factors (such as use of solvents, preparation technique, master apical gauge tip size, gutta percha, root canal sealant, core fillings and time taken to complete treatment) were kept constant as much as clinically possible so that the results could be compared.

Materials and Method

The trial was carried out in four different private practices in the United Kingdom by the same practitioner. Consent for retreatment was obtained from all patients. The study was begun in November 2004 and continued through July 2006. All patients presenting for retreatment were included in the study. They were in good health and between the ages of 26-75 years. There were 58 females and 24 males. The patients were referred for retreatment by their general dentists for a number of reasons, such as, a past history of an abscess, a symptomless lesion under a root treated tooth found following dental consultation, crowns needing replacement with failing root treatment, a sinus draining, mobile tooth , tooth sore on biting, and post and crown loose.
The patients' history was taken and the teeth were assessed for percussion, mobility, periodontal pocketing, sinus, and an x-ray was taken. The preoperative x-rays were taken to assess the "root" cause of failure of the present root canal treatment. The root canal treatment was assessed for correct length (underextended or overextended) and fill, difficulty of root anatomy (sharp curvature), root to crown ratio, loss of periodontal attachment, whether the tooth is an abutment or not, coronal leakage present, size of lesion (measured as an average size on computer), post length, missed canals, and restorability.

82 teeth were considered for this clinical study. The teeth were mostly lower first molars (17); upper first molars (14); upper second premolars (11); upper first premolars (7); central incisors (6); upper canines and upper lateral incisors (5); lower first and second premolars (4); lower second molars and lower central incisors (3); upper second molars (2) and lower second premolar (1).

The teeth were isolated by rubber dam and in some cases the teeth were anaesthetised by local infiltration or mandibular block. The teeth were re-entered by tapered round-ended diamond burs in a turbine hand-piece. In those cases where a post and crown was present, the crown was destroyed and the post was removed atraumatically. The post was removed in the following general manner: the core shoulder was removed by a diamond bur in a turbine in order to expose the post. The practitioner was careful not to remove dentine and the ferrule as much as clinically possible. A Mueller bur or LN bur (D0205, by Dentsply) was used to drill along and around the post up to 3mm. In this way a space was created around the coronal portion of the post. An ultrasonic tip is then leant against the post and remaining core and the post/core is vibrated into this space and is dislodged in this manner.

The access to the canal was then enlarged by Gates Glidden burs size no. 4# and sometimes size no. 6# for large canal openings. The chamber was flooded with chloroform and the canals were cleaned and shaped with NiTi rotary files in a slow speed reducing hand-piece (75:1). The current study included the comparison of two types of file systems on the market- variable taper (ProTaper, by Dentsply) with constant 06 taper file (K3, by Dentsply). The rotary file systems (Protaper and K3) were alternated after every patient. The files were marked after each patient and discarded after they were used in three teeth. Working length was established with the use of pre-operative x-ray, apex locator (Root ZX, by Morita) and by confirming radiographically with a file in position. The x-rays taken were digital x-rays with Schick technologies software (Schick Technologies Inc., Long Island City, NY, USA). The canals were reshaped with a crown-down approach to finish, and, if clinically possible, the last file size tip was kept to size 25# as much as clinically possible.

The canals were irrigated with 3% sodium hypochlorite, home "bleach" (NaOCl) after every file used. All files were liberally coated with a chelating agent, Glyde (Dentsply). After shaping the canals with rotary files, the canals were finished off with a few strokes of a Hedstroem filing (usually size no. 30#, just short of the confirmed apex).

Where ledges were encountered, they were bypassed with the use of Flex-o-files and Hedstroem and GT files. The ledges were usually removed or corrected in the following manner: firstly, the correct working length was re-established with the use of a precurved K-type hand file of gauge 08# or 10#. A precurved Hedstroem file 10# or 15# was then used to widen the "glide path" to the apex. Once the file was renegotiated past the ledge, the Hedstroem file was lightly rotated so that the curved file would "work" around the ledge. The Hedstroem files would be worked up to size 25#. A System GT hand file was sometimes used in order to speed up the ledge removal.

The canals were then soaked with chloroform again and paper points were used to wick out remnants of gutta percha, or just to confirm that canals were finally clean of old gutta percha. The canals were then finally irrigated with 3% NaOCl and dried with paper points. Gutta percha points matching the rotary file system used (Profit 06, Dentsply) for Potaper and non-standardised F-M or M size (Kerr) and matching the last file tip used to the apex was inserted into the canals and the length was checked and cut to fit. The gutta percha points were lightly buttered with AH plus root canal sealant and reinserted and an x-ray was taken to confirm a good fit. The gutta percha was sealed and compacted into the canals with the use of System B as directed by Buchanan LS, (1998). The coronal portion was either back-filled by means of the Obtura technique (SybronEndo – USA) or left empty to receive a glass fibre post.

The retreatment procedure was performed mostly as a single appointment. The appointment was usually not longer than one and a half hours when including the post core filling. Where and when necessary, a glass fibre post (DT Light Post, RTD) was selected according to canal size and the post space was drilled out with an appropriate drill. The glass fibre posts were bonded into the canal with RelyX ARC (by 3M ESPE). The cores were built up with composite (Herculite XRV, by Kerr) and in those cases where a crown was present and not changed, the access was sealed with a composite material.

The patients were followed up after 1 and 4 months and 1 year post-operatively. The teeth were checked for percussion discomfort, periodontal pockets, mobility, presence of a sinus, coronal restoration or extracted. X-rays were taken to assess healing.

Please see examples or recorded results at Adendum page 122 at end of thesis.

Results

Tabulation of collected measurements on Root Canal Treatments versus Final Definition of "Failure" or "Success"

The "Failure" of the root canal treatment was re-defined to simplify it and to reduce the number of classes, however, three of the treatments could not be classified as a "Success" or "Failure". The table below provides the frequencies of the teeth classified according to the "Success" or "Failure" status and the three age classes.

In the final edited data set there were 81 different root canal treatments of which ten were "Failures" and 68 turned out to be "Successes", however, three teeth could not be classified due to the absence or non-return of the patients. The counts in the last column (10 and 68) are called the marginal totals.

Table 1

Frequency table of "Age" categories versus "Success" or "Failure"

		Age Categories			
Failure or Success		1_<40	2_41-55	3_>55	Total
Failure	Frequency	1	7	2	10
	Row Percentage	10%	70%	20%	
Success	Frequency	18	34	16	68
	Row Percentage	26%	50%	24%	
Total		20	41	20	81

Due to the small number of "Failures" (10) the percentages were provided only for illustrative and comparative purposes. Furthermore, the tests used for analysis have low power for the same reason (low number of "Failures" (ten)).

The examples below (left to right) of before and after of successful outcome, failing, and unsure results of retreatments:

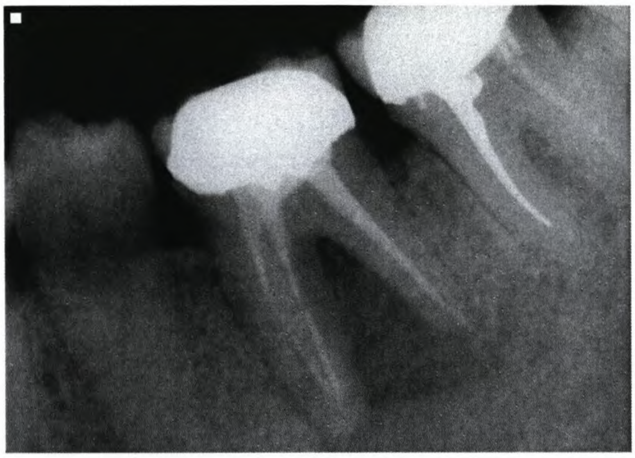
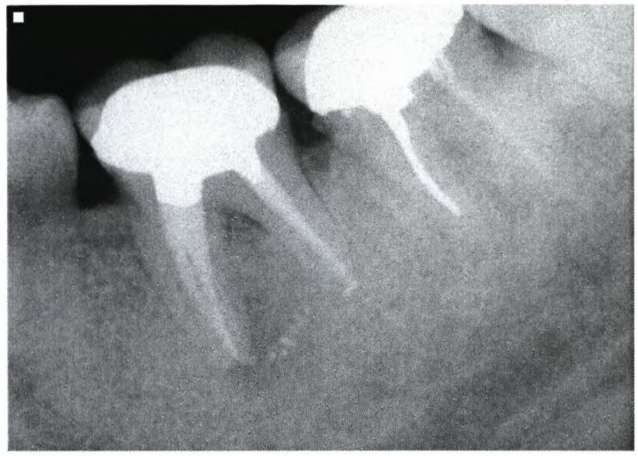
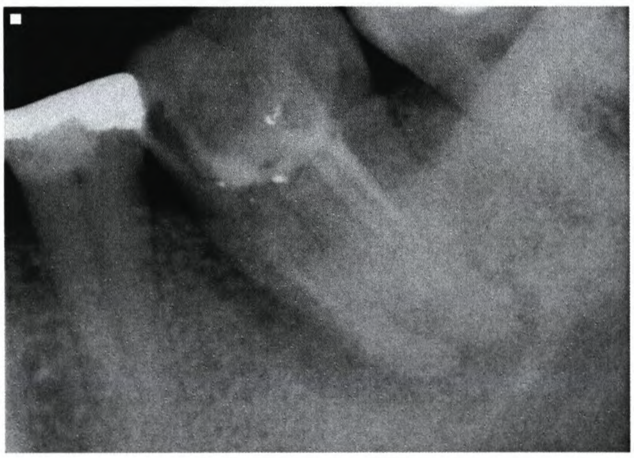
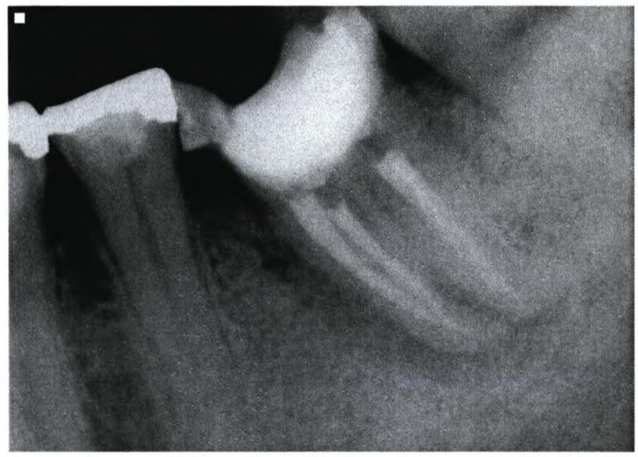





Table 2

Frequency table of "Gender" versus "Success" or "Failure"

		Gender		
Failure or Success	Data	Females	Males	Total
Failure	Frequency	4	6	10
	Row Percentage	40%	60%	100%
Success	Frequency	50	18	68
	Row Percentage	74%	26%	100%
Total		54	24	78

According to the Fisher Exact Test the rates of "Failure" did not differ significantly for the two genders ("Failure" rate for Females was 7% and for the Males 25%, column percentages, to show the similarity between the row and column arguments). *These two rates appear to be different but statistically the p-value is equal to 0.07.*

Table 3

Frequency table of "Post-op Pain" versus "Success" or "Failure"

		Pain		
Failure or Success	Data	No	Yes	Total
Failure	Frequency	7	3	10
	Row Percentage	70%	30%	100%
Success	Frequency	62	6	68
	Row Percentage	91%	9%	100%
Total		69	9	78

Within the "Failure" group there were three cases that experienced pain (30%) and in the "Success" group there were only six individuals that experienced pain (9%). The exact significance level (Fisher Test) was less than 9%.

Table 4

Frequency table of "Quadrant" categories versus "Success" or "Failure"

	Quadrant				
	1	2	3	4	Total
Frequency	21	28	16	16	81
Row Percentage	26%	35%	20%	20%	100%

From the table above it could be seen that most of the root canal treatments occurred in Quadrant Two. The distribution of "Success" and "Failure" did not differ between the various quadrants due to the low number of "Failures".

Table 5

Frequency table of “Position” categories versus “Success” or “Failure”

	Position 1≡Front teeth … 6,7≡Molars							
	1	2	3	4	5	6	7	Total
Frequency	9	4	5	12	16	30	5	81
Row Percentage	11%	5%	6%	15%	20%	37%	6%	100%

From the table above it could be observed that most of the root canal treatments occurred somewhat more towards the molars. However, there was not enough “Failures” to establish whether this pattern was significant.

Table 6

Frequency table of “Mobility” versus “Success” or “Failure”

		Mobility		
Success/”Failure		No	Yes	Total
Failure	Frequency	7	3	10
	Row Percentage	70%	30%	100%
Success	Frequency	61	7	68
	Row Percentage	90%	10%	100%
Total		68	10	78

Although the two estimated proportions of mobility (30% and 10%) in the “Failure” and “Success” groups appear to be different it was not significantly different ($p>0.10$).

After some collapsing the TTP codes resulted in the table below.

Table 7

Frequency table of "TTP" categories versus "Success" or "Failure"

		TTP		
Failure or Success		1-4 or Yes	No	Total
Failure	Frequency	5	5	10
	Row Percentage	50%	50%	100%
Success	Frequency	15	53	68
	Row Percentage	22%	78%	100%
Total		20	58	78

Although the two estimated proportions of "TTP" present (50% and 78%) in the "Failure" and "Success" group appear to be different it was not significantly different ($p>0.10$).

Table 8

Frequency table of "Periodontal Pocketing CPITN" categories versus "Success" or "Failure"

		Periodontal Pocketing CPITN		
Failure or Success		1	blank&2-4	Total
Failure	Frequency	6	4	10
	Row Percentage	60%	40%	100%
Success	Frequency	59	9	68
	Row Percentage	87%	13%	100%
Total		65	13	78

The two estimated proportions of "Periodontal Pocketing CPITN" present (40% and 13%) in the "Failure" and "Success" group were significantly different ($p<0.10$).

Table 9

Frequency table of "Sinus" versus "Success" or "Failure"

		Sinus		
Failure or Success		No	Yes	Total
Failure	Frequency	4	6	10
	Row Percentage	40%	60%	100%
Success	Frequency	61	7	68
	Row Percentage	90%	10%	100%
Total		65	13	78

The two estimated proportions of "Sinus" present (60%) in the "Failure" group and 10% in the "Success" group were significantly different ($p<0.01$). "Sinus present" in the "Success group" means in the initial clinical assessment *before* retreatment was initiated.

Table 10

Frequency table of "Abutment/crown" versus "Success" or "Failure"

		Abutment/crown		
Failure or Success		No	Yes	Total
Failure	Frequency	5	5	10
	Row Percentage	50%	50%	100%
Success	Frequency	24	44	68
	Row Percentage	35%	65%	100%
Total		29	49	78

No statistical difference was found between the two proportions of "Abutment/crown" (50% and 65%) within the "Failure" and "Success" groups ($p>0.10$).

Table 11

Frequency table of "Occlusion" versus "Success" or "Failure"

		Occlusion		
Failure or Success	Data	No	Yes	Total
Failure	Frequency	2	8	10
	Row Percentage	20%	80%	100%
Success	Frequency	1	67	68
	Row Percentage	1%	99%	100%
Total		3	75	78

The two estimated proportions of "Occlusion" present (80% and 99%) in the "Failure" and "Success" group were significantly different ($p<0.05$). Therefore, teeth in "occlusion" were more within the "Success" group.

Table 12

Frequency table of "History of trauma" versus "Success" or "Failure"

		History of trauma		
Failure or Success		No	Yes	Total
Failure	Frequency	10	0	10
	Row Percentage	100%	0%	100%
Success	Frequency	67	1	68
	Row Percentage	99%	1%	100%
Total		77	1	78

Clearly there is no difference between the "Failure" and "Success" groups with respect to the "History of Trauma".

Table 13

Frequency table of "Tooth cracked" categories versus "Success" or "Failure"

		Tooth cracked			
Failure or Success		?	No	Yes	Total
Failure	Frequency		9	1	10
	Row Percentage	0%	90%	10%	100%
Success	Frequency	1	67		68
	Row Percentage	1%	99%	0%	100%
Total		1	76	1	78

Studying the above table it is clear that the "No"-column contains 98% of the observations. It is therefore not worthwhile to investigate for differences between the "Failure" and "Success" groups. "Undecided" (? above) classes is difficult to handle in the process of making inferences of data. It is usually merged with other categories, if applicable, or excluded. No "Specific tooth characteristics" were noted and therefore no inference was made.

Table 14

Frequency table of "Apical Rarefaction (mm)" categories versus "Success" or "Failure"

		Apical Rarefaction (mm)		
Failure or Success		Below 6.0	6 and more	Total
Failure	Frequency	3	7	10
	Row Percentage	30.0%	70.0%	100.0%
Success	Frequency	52	16	68
	Row Percentage	76.5%	23.5%	100.0%
Total		55	23	78

The differences between the collapsed categories were significant according to Fisher's Exact Test ($p<0.01$).

The original data contained Blanks and was reduced to the table below by removing the Blanks

Table 15

Frequency table of "Diffuse/Well-defined" versus "Success" or "Failure"

		Diffuse/Well-defined		
Failure or Success		Diffused	Well-defined	Total
Failure	Frequency	4	5	9
	Row Percentage	44%	56%	100%
Success	Frequency	53	3	56
	Row Percentage	95%	5%	100%
Total		57	8	65

The categories "Diffuse" or "Well-defined" were distributed differently between the rows "Failure" and "Success" ($p<0.001$)

The information available on "Post present (mm to apex)" was reduced (collapsed) into the table below.

Table 16

Frequency table of "Post present" versus "Success" or "Failure"

		Post present		
Failure or Success	Data	No	Yes	Total
Failure	Frequency	10	0	10
	Row Percentage	100.0%	0.0%	100.0%
Success	Frequency	47	21	68
	Row Percentage	69.1%	30.9%	100.0%
Total		57	21	78

The two estimated proportions of "Post present" (0% and 31%) in the "Failure" and "Success" groups were significantly different ($p<0.10$). Therefore, the "Post was present" in many more cases within the "Success" group than in the "Failure" group.

The occurrence of the "Presence of apicoectomy" was so low that it is not worthwhile to perform any statistical testing.

There was no difference between the Median "Crown/Root" ratios of the "Failure" (Median = 0.595) or "Success" groups (Median = 0.662) (Wilcoxon Test, $p>0.10$).

Only two cases of "Yes - External resorption present" occurred in the "Success" group, therefore, here was no difference between the "Failure" and "Success" groups with respect to "External resorption".

This measurement of the "Length of roots (mm)" was made on the interval scale and the rank statistics is given below.

Table 17

Descriptive statistics of "Length of roots (mm)" within the "Success" and "Failure" groups.

	Descriptive Statistics of "Length of roots (mm)"	
	Success Group	Failure Group
Count	68	10
Minimum	7.6	15.9
Quartile 1	19.3	20.825
Quartile 2 (Median)	20.5	22
Quartile 3	21.725	24.675
Maximum	28	30.8

Teeth with long roots tend to lead to failure, however there was considerable overlap between the distributions. Therefore the finding is that the Median length of the roots of the "Failures" is longer than that of the "Successes". (Wilcoxon Rank Sum Test, p-value = 0.0628).

Table 18

Frequency table of "Complexity of anatomy of roots (curved)" versus "Success" or "Failure"

		Complexity of anatomy of roots (curved)		
Failure or Success		No	Yes	Total
Failure	Frequency Row Percentage	8 80%	2 20%	10 100%
Success	Frequency Row Percentage	53 78%	15 22%	68 100%
Total		61	17	78

No difference occurred in the rate of "Complexity of anatomy of roots (curved)" between the "Success" and "Failure" groups.

Table 19

Frequency table of "Leaking coronal restoration" versus "Success" or "Failure"

		Leaking coronal restoration		
Failure or Success		No	Yes	Total
Failure	Frequency Row Percentage	6 60%	4 40%	10 100%
Success	Frequency Row Percentage	50 74%	18 26%	68 100%
Total		56	22	78

No difference occurred in the rate of "Leaking coronal restoration" between the "Success" and "Failure" groups p>0.10). This finding was of teeth before retreatment was performed.

Furcation boneloss was present in only two cases in the "Success" group and none in the "Failure" group (not significant).

Table 20

Frequency table of "Boneloss present, involving one root" versus "Success" or "Failure".

		Boneloss present, involving one root		
Failure or Success		No	Yes	Total
Failure	Frequency	8	2	10
	Row Percentage	80.0%	20.0%	100.0%
Success	Frequency	60	8	68
	Row Percentage	88.2%	11.8%	100.0%
Total		68	10	78

Boneloss involving one root was present in only two cases in the "Failure" group and eight in the "Success" group (not significant).

Only one case of "Boneloss involving two roots" was present in the "Success" group and none in the "Failure" group (not significant).

Table 21

Frequency table of "Obturation to WL" versus "Success" or "Failure"

		Obturation to WL		
Failure or Success		No	Any Yes	Total
Failure	Frequency	5	5	10
	Row Percentage	50%	50%	
Success	Frequency	55	13	68
	Row Percentage	81%	19%	
Total		60	18	78

After considerable collapsing of the information on "Obturation to WL" the above table was constructed which yielded a significant difference between the "Failure" and "Success" groups (Fisher Exact Test, $p<0.05$). This table indicates previous short root filling that indicated the *preparation* was short contributes to the final success of retreatment.

Table 22

Frequency table of "Obturation Short" versus "Success" or "Failure"

		Obturation Short		
Failure or Success		1 & 2 (Yes)	No	Total
Failure	Frequency	5	5	10
	Row Percentage	50.0%	50.0%	100.0%
Success	Frequency	60	8	68
	Row Percentage	88.2%	11.8%	100.0%
Total		65	13	78

After considerable collapsing of the information on "Obturation Short" of the initial root filling, the above table was constructed which yielded a significant difference between the distribution of the "Failure" and "Success" groups (Fisher Exact Test, $p<0.01$).

Only one case of "Over extension" was present in the "Success" group and none in the "Failure" group (not significant).

Table 23

Frequency table of "Unlocated canal(s)" versus "Success" or "Failure"

		Unlocated canal(s)		
Failure or Success	Data	N	Yes	Total
Failure	Frequency	4	6	10
	Row Percentage	40%	60%	100%
Success	Frequency	43	25	68
	Row Percentage	63%	37%	100%
Total		44	31	78

No statistical difference occurred between the estimated proportions of "Unlocated canal(s)"in the "Failure" and "Success" groups ($p>0.10$).

Only one case of "Silverpoint failing" was present in the "Success" group (initial assessment) and none in the "Failure" group (not significant). Three cases of "Broken instruments (apical, mid-root)" were present in the "Success" group (initial assessment) and none in the "Failure" group (not significant).

No perforations occurred at all in this study.

Table 24

Frequency table of “N2 Paste” versus “Success” or “Failure”

		N2 paste		
Failure or Success	Data	No	Yes	Total
Failure	Frequency	9	1	10
	Row Percentage	90%	10%	100%
Success	Frequency	67	1	68
	Row Percentage	99%	1%	100%
Total		76	2	78

Only two case of “N2 Paste” was present, one in the “Success” group and one in the “Failure” group (rates not significantly different).

Table 25

Frequency table of “Ledges” versus “Success” or “Failure”

		Ledges		
Failure or Success	Data	No	Yes	Total
Failure	Frequency	4	6	10
	Row Percentage	40%	60%	100%
Success	Frequency	30	38	68
	Row Percentage	44%	56%	100%
Total		34	44	78

No statistical difference was present with respect to the proportion of “Ledges”.

The next measurements (or tables) refer to the "Final Retreatment characteristics".

Table 26a

Frequency table of "K3 Files" versus "Success" or "Failure"

		K3 Files					
Failure or Success		20	25	30	60	No	Total
Failure	Frequency		5	1		4	10
	Row Percentage	0%	50%	10%	0%	40%	100%
Success	Frequency	1	30	4	1	32	68
	Row Percentage	1%	44%	6%	1%	47%	100%
Total		1	37	6	1	36	81

It is highly unlikely that the gauge of K3 Files influenced the success of the root canal treatment in this study.

The information provided on the gauge of K3 Files used was collapsed in the table below.

Table 26b

Frequency table of "K3 Files used" versus "Success" or "Failure"

		K3 Files used		
Failure or Success		Yes	No	Total
Failure	Frequency	6	4	10
	Row Percentage	60%	40%	
Success	Frequency	36	32	68
	Row Percentage	53%	47%	
Total		42	36	78

According to the information provided on the usage of "K3 Files" and the gauges used no difference could be detected between the "Failure" and "Success" groups.

Table 27a

Frequency table of "Protaper" versus "Success" or "Failure"

		Protaper							
Failure or Success		20	25	30	20/25	25/30	40/25	No	Total
Failure	Frequency		4					6	10
	Row Percentage	0%	40%	0%	0%	0%	0%	60%	100%
Success	Frequency	1	24	4	1	2	1	35	68
	Row Percentage	1%	35%	6%	1%	3%	1%	51%	100%
Total		1	28	4	1	2	1	44	81

Table 27b

Frequency table of "Protaper File" versus "Success" or "Failure"

	Protaper File			
Failure or Success		Yes	No	Total
Failure	Frequency Row Percentage	4 40%	6 60%	10
Success	Frequency Row Percentage	33 49%	35 51%	68
Total		37	41	78

According to the information provided on the usage of "Protaper Files" and the gauges used no difference could be detected between the "Failure" and "Success" groups. "K3 Files" was used a little bit more frequent (54%) than the "Protaper Files" (47%) excluding the three cases where the patients did not return to be evaluated.

Respectively the "Successes" with K3 File (35 out of 41) was 85%; and with Protaper File (32 out of 36) was 89%. One case was observed where both the files were used. The "Success" rate certainly was not different between the two file types.

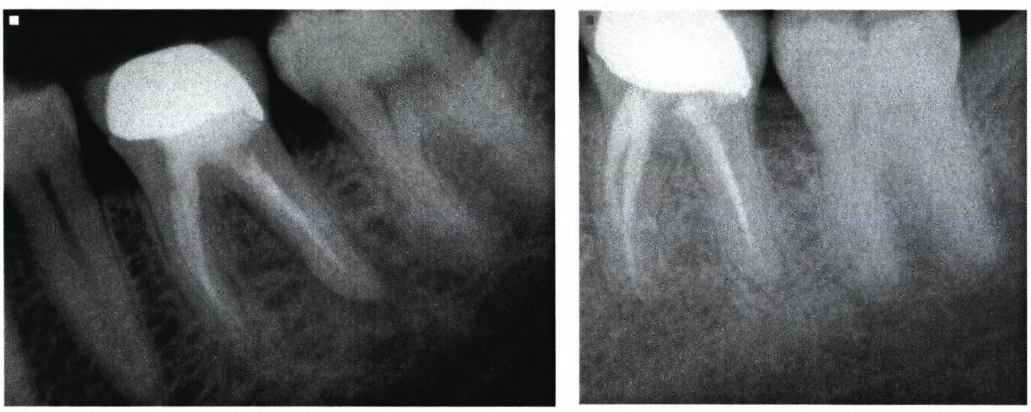
After some collapsing the contingency table of "Failure or Success" versus "Accessory/lateral canals" resulted in the table below.

Table 28

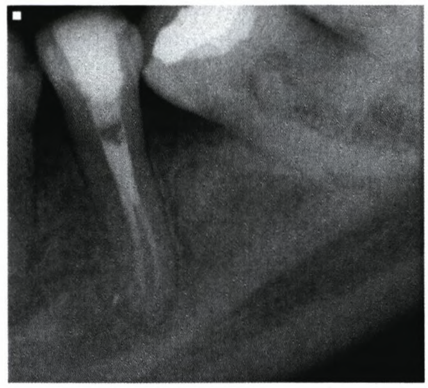
Frequency table of "Accessory/lateral canals" versus "Success" or "Failure"

		Accessory/lateral canals		
Failure or Success		No	Yes (Y,YP)	Total
Failure	Frequency	10	0	10
	Row Percentage	100%	0%	100%
Success	Frequency	53	15	68
	Row Percentage	78%	22%	100%
Total		63	15	78

No "Accessory/lateral canals" occurred within the Failures and 15 cases occurred in the "Success" group, however, the rates thereof did not differ significantly.



Above is an example of a retreatment case demonstrating an accessory canal.

Above is an example of the successful outcome of retreating a case exhibiting the complexity of the root canal system.

Table 29a

Frequency table of "Obturation to WL" versus "Success" or "Failure"

		Obturation to WL			
Failure or Success		No	Yes	Y_N	Total
Failure	Frequency	1	6	3	10
	Row Percentage	10%	60%	30%	100%
Success	Frequency	6	60	2	68
	Row Percentage	9%	88%	3%	100%
Total		7	66	5	78

Various methods of collapsing is possible for the above table, the one below resulted in a significant difference (Fisher's Exact Test, $p<0.05$)

Table 29b

Frequency table of "Obturation to WL" versus "Success" or "Failure"

		Obturation to WL		
Failure or Success		No & YN	Yes	Total
Failure	Frequency	4	6	10
	Row Percentage	10%	60%	100%
Success	Frequency	8	60	68
	Row Percentage	12%	88%	100%
Total		12	66	78

In the next collapsed table the difference is not significant anymore. The information contained in the original two-way table (Table 29a) was recalculated in two ways: Table 29b and 29c. It can be seen as inconsistent if the two tables provide different outcomes. This appears to be illogical and therefore, it could not be stated that there was a difference in "Success" rates

Table 29c

Frequency table of "Obturation to WL" versus "Success" or "Failure".

		Obturation to WL		
Failure or Success		No	Yes & YN	Total
Failure	Frequency	1	9	10
	Row Percentage	10%	90%	100%
Success	Frequency	6	62	68
	Row Percentage	9%	91%	100%
Total		7	71	78

After collapsing the codes of "Obturation Short" it resulted in the following table.

Table 30

Frequency table of "Obturation Short" categories versus "Success" or "Failure"

		Obturation Short (mm)		
Failure or Success		No	Yes	Total
Failure	Frequency	6	4	10
	Row Percentage	60%	40%	100%
Success	Frequency	60	8	68
	Row Percentage	88%	12%	100%
Total		66	12	78

According to the information provided on "Obturation Short" no difference could be detected between the "Failure" and "Success" groups.

Table 31

Frequency table of "Over Extension (mm)" categories versus "Success" or "Failure"

		Over Extension (mm)		
Success/Failure	Data	0.5 & 1.0mm	No	Total
Failure	Frequency	0	10	10
	Row Percentage	0%	100%	100%
Success	Frequency	3	65	68
	Row Percentage	4%	96%	100%
Total		3	75	78

Collapsing over columns 0.5 & 1.0mm results in the table above. From this table it could be deduced that the problem of "Overextension" did not occur often in this study.

Combining Previous and Retreatment

Combining "Obturation to WL *Previous*" and "Obturation to WL *Retreatment*" into a single table and removing the "Blanks" of "Success or Failure" resulted in the following table.

Table 32

Frequency table of "Obturation to WL Retreatment" categories versus "Success" or "Failure"

	Obturation to WL_Retreatment			
Obturation to WL_Previous	No	Yes/No	Yes	Total
No	6	3	51	60
Yes/No		1	4	5
Yes	1	1	11	13
Total	7	5	66	78

The total count of the diagonal cells was low indicating that in only eighteen teeth the same treatment was applied on both occasions. It was indicated that sixty (were treated differently on the two occasions) did not receive "Obturation" treatment previously. Of these 60 teeth fifty-four (51 + 3) were retreated with respect to "Obturation". The essence of the above exercise was to study changes from Previous to Retreatment and not to decide whether the change was statistically significant.

Table 33

Frequency table of "Obturation Short Retreatment" categories versus "Success" or "Failure"

Success/Fail	(All)	Blanks removed

	Obturation Short Retreatment		
Obturation Short Previous	No	Yes	Total
Yes	54	11	65
No	12	1	13
Total	66	12	78

The previous failing root treatment measurements stated that 65 teeth had "Obturation Short" of which 54 were not "Obturation short" during the retreatment and the other 11 were "Obturation Short". Of the 13 teeth indicated as "Obturation not Short" previously, 12 were indicated as "Obturation Short" after retreatment. The aim of the above exercise was for comparative purposes and not to determine significance.

Table 34

Frequency table of "Obturation Root" categories versus "Success" or "Failure"

Success/Fail	(All)	Blanks removed

	Obturation Root		
Obturation to WL_Previous	Yes	(blank) or No	Total
No	9	51	60
NY(one canal yes; one canal no)	2	3	5
Yes	1	12	13
Total	12	66	78

After some collapsing the table above was constructed in which "Obturation to WL Previously" was combined with "Obturation Root (all measured readings were assumed to be Yes)".

The light green shaded cells highlight those counts that were similar between the two occasions. The above table indicates a high number of off-diagonal cells that have changed between the two occasions. The aim of the above exercise was for comparative purposes and not to determine significance.

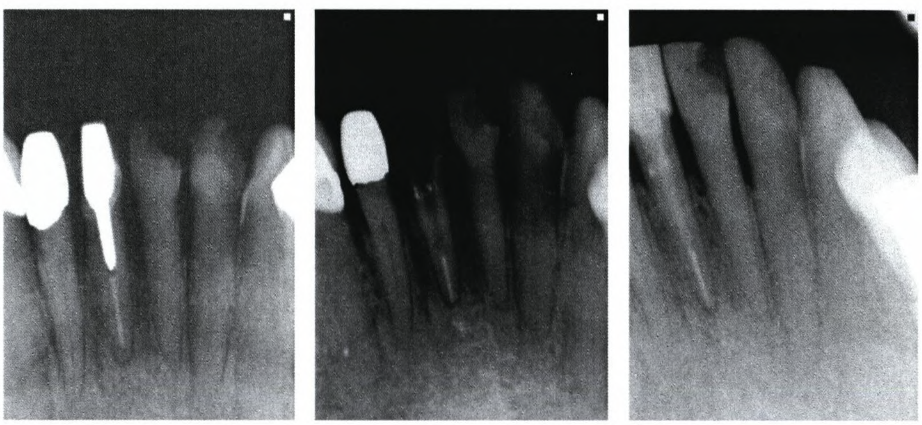
Back to Risks of single measurements.

Table 35

Frequency table of "Post bonded" categories versus "Success" or "Failure"

		Post bonded		
Failure or Success		No	Yes	Total
Failure	Frequency	10	0	10
	Row Percentage	100%	0%	100%
Success	Frequency	35	33	68
	Row Percentage	51%	49%	100%
Total		45	33	78

A difference occurred in the percentages of "Yes" for "Post was bonded" within the "Success" and "Failure" groups (Fisher's Exact Test p<0.01). It might be deduced that "Post bonding" or immediate post placement was a contributing factor for "Success".



Above is an example of retreating a tooth with an immediate placement of bonded post and core (left to right).

Table 36

Frequency table of "Composite core" categories versus "Success" or "Failure"

		Composite core		
Failure or Success		No	Yes	Total
Failure	Frequency	7	3	10
	Row Percentage	70%	30%	100%
Success	Frequency	21	47	68
	Row Percentage	31%	69%	100%
Total		28	50	78

A considerable difference occurred in the percentages of the "Yes" for "Composite core" within the "Success" and "Failure" groups (Fisher's Exact Test $p<0.0001$). It might be deducted that "Composite core" was a contributing factor for "Success".

Table 37

Frequency table of "Bonded amalgam core" categories versus "Success" or "Failure".

		Bonded amalgam core		
Failure or Success		No	Yes	Total
Failure	Frequency	10	0	10
	Row Percentage	100%	0%	100%
Success	Frequency	64	4	68
	Row Percentage	94%	6%	100%
Total		77	4	81

The difference between the "Yes- Bonded amalgam core" rates was not significant for the "Success" and "Failure" groups ($p>0.05$).

The "Microscope" was only used once during the study and did not contribute anything to the "Success" or "Failure".

Table 38

Frequency table of "Interception times in months" categories versus "Success" or "Failure"

		Interception times (months)			
Success/Failure		Less than 6	7 to 12	(blank) or No	Total
Failure	Frequency	2	0	8	10
	Row Percentage	20%	0%	80%	100%
Success	Frequency	4	8	56	68
	Row Percentage	6%	12%	82%	100%
Total		6	8	64	78

In the table 38 (collapsed) there was no difference between the row percentages of the "Interception times (months)" for the "Success" and "Failure" groups.

Table 39

Frequency table of "One or multiple appointments" categories versus "Success" or "Failure"

		One or multiple appointments			
Failure or Success		1	2	3	Total
Failure	Frequency	9	1		10
	Row Percentage	90%	10%	0%	100%
Success	Frequency	60	7	1	68
	Row Percentage	88%	10%	1%	100%
Total		72	8	1	81

No differences occurred in the row percentages of "One or multiple appointments" for the "Success" and "Failure" groups.

Table 40

Frequency table of "Inter-appointment medicaments" categories versus "Success" or "Failure".

		Inter-appointment medications		
Failure or Success		No	Yes	Total
Failure	Frequency	10		10
	Row Percentage	100%	0%	100%
Success	Frequency	67	1	68
	Row Percentage	99%	1%	100%
Total		80	1	81

Medicaments for use between appointments was prescribed only once during this study.

One Month follow-up visit follows below:

25 patients/teeth were not present at 1 month

Table 41

Frequency table of “Diminished Rarefaction” categories versus “Success” or “Failure”

		Diminished Rarefaction		
Failure or Success		No	Yes	Total
Failure	Frequency	5	4	9
	Row Percentage	56%	44%	100%
Success	Frequency	14	32	46
	Row Percentage	30%	70%	100%
Total		19	36	55

The sample of teeth evaluated was reduced by approximately 23, this might lead to bias in the sample and therefore, it would not be useful to determine whether the difference between the “Success” and “Failure” groups was significant. However, a statistical test was performed on the reduced table above and it turned out to be not significant.

Table 42

Frequency table of "Pain" categories versus "Success" or "Failure"

		Pain at One Month		
Failure or Success		No	Yes	Total
Failure	Frequency	6	2	8
	Row Percentage	75%	25%	100%
Success	Frequency	45	1	46
	Row Percentage	98%	2%	100%
Total		51	3	54

The difference in row percentages for "Pain at One Month" between the "Failure" and "Success" groups was significant with the level between 5% and 10%. A comparative analysis between "Initial Pain" and "Pain at One Month" was not performed because of the 23 missing values at "One Month".

Table 43
Frequency table of the classification of the "Initial Mobility" versus "One Month Mobility" of the complete sample with the three "Blanks" removed. (Diagonal cells indicated)

	One Month Mobility			
Initial Mobility	2	No	Patient Absent	Total
1	0	3	0	3
2	4 (2)	0	1	5 (2)
3	1	0	0	1
N	0	46 (6)	22 (1)	68 (7)
Y	0	1 (1)	0	1 (1)
Total	5 (2)	50 (7)	23 (1)	78 (10)

The table above describes the "Mobility" count in the cells ("Initial Mobility", "One Month Mobility") where the complete sample of 78 was classified, and also the counts of the "Absent Patients". The count (frequency) of the "Failures" is displayed in brackets and the rate of "Failures" is in general extremely low. Comparing "One Month Mobility" on its own with respect to "Success" and "Failure" resulted in row percentages (in a sparse table) that were not significantly different from each other in the two groups (table not displayed here). From the above table it was evident that a large proportion (23 individuals or teeth) of the "Success" group did not turn up at the "One Month Visit". This would affect the possible differences between the "Failure" rates in the different classes, for example "One Month Mobility" and other measurements at "One Month Visit". The exclusion of the information of the "Absent Patients" does not solve the problems (bias) it creates in the analysis of the "One Month Visit" results. The above table was constructed to compare "Initial Mobility" and "One Month Mobility" and the position of the "Failures". The lesson from the above table is that the subjects did not turn-up for the "One Month" visit.

Due to the high number of "Absent Patients" (23 to 25) at the "One Month Visits" only the marginal frequencies of "TTP", "Periodontal Pocketing", "Sinus" and "Extracted" were given in Table 44a to 44e.

Table 44a

The results of "TTP at One Month"

	TTP at One Month				
Classes	1	3	N	Patient Absent	Total
Frequencies	6	1	48	23	78

Table 44b

The results of "Peridontal Pocketing CPITN at One Month"

	Periodontal Pocketing CPITN at One Month						
Classes	1	2	3	4	N	Patient Absent	Total
Frequencies	49	1	3	1	1	23	78

Table 44c

The results of "Sinus at One Month"

	Sinus at One Month			
Classes	No	Yes	Patient Absent	Total
Frequencies	51	4	23	78

Table 44d

The results of "Coronal Restoration at One Month"

	Coronal restoration at One Month			
Classes	No	Yes	Patient Absent	Total
Frequencies	39	16	23	78

Table 44e

The results of "Extracted at One Month"

	Extracted at One Month		
Classes	No	Patient Absent	Total
Frequencies	55	23	78

No extractions were made in this data set.

Due to the fifteen "Absent Patients" at the "Four Months Visits" only the marginal frequencies of "Diminished Rarefaction", "Pain", "Mobility", "TTP", "Periodontal Pocketing", "Sinus", "Coronal Restoration" and "Extracted" were given in Table 45a to 45h.

Table 45a

The results of "Diminished Rarefaction at Four Months"

	Diminished rarefaction at Four Months			
Classes	N	Y	Patient Absent	Total
Frequencies	12	51	15	78

It is noted that cases that were successful had diminished rarefaction at the four month review.

Table 45b

The results of "Pain at Four Months"

	Pain at Four Months			
Classes	No	Yes	Patient Absent	Total
Frequencies	60	3	15	78

Table 45c

The results of "Mobility at Four Months"

	Mobility at Four Months					
Classes	1	2	3	No	Patient Absent	Total
Frequencies	5	1	1	56	15	78

Table 45d

The results of "TTP at Four Months"

	TTP at Four Months					
Classes	1	3	No	Yes	Patient Absent	Total
Frequencies	3	1	58	1	15	78

Table 45e

The results of "Periodontal Pocketing CPITN at Four Months"

	Periodontal pocketing CPITN at Four Months				
Classes	1	2	3	Patient Absent	Total
Frequencies	55	5	3	15	78

Table 45f

The results of "Sinus at Four Months"

	Sinus at Four Months			
Classes	No	Yes	Patient Absent	Total
Frequencies	58	5	15	78

Table 45g

The results of "Coronal Restoration at Four Months"

	Coronal restoration at Four Months			
Classes	No	Yes	Patient Absent	Total
Frequencies	34	29	15	78

Table 45h

The results of "Extracted at Four Months"

	Extracted at Four Months			
Classes	No	Yes	Patient Absent	Total
Frequencies	61	2	15	78

Due to the six to nine "Absent Patients" at the "One Year Visit" only the marginal frequencies of "Diminished Rarefaction", "Diminished Root", "Pain", "Mobility", "TTP" and "Periodontal Pocketing CPITN" were given in Table 46a to 46f.

Table 46a
The results of "Diminished Rarefaction at One Year"

	Diminished Rarefaction at One Year				
Classes	No	Yes	(blank)	Patient Absent	Total
Frequencies	7	64	1	6	78

Table 46b

The results of "Diminished Root Classes at One Year"

	Diminished Root Classes at One Year				
Classes	1_Hardly	2_ >0.2	(blank)	Patient Absent	Total
Frequencies	53	18	1	6	78

Table 46c

The results of "Pain at One Year"

	Pain at One Year				
Classes	No	Yes	(blank)	Patient Absent	Total
Frequencies	71	1	1	5	78

Table 46d

The results of "Mobility at One Year"

	Mobility at One Year				
Classes	1	N	(blank)	Patient Absent	Total
Frequencies	1	71	1	5	78

Table 46e

The results of "TTP at One Year"

	TTP at One Year					
Classes	1	2	N	(blank)	Patient Absent	Total
Frequencies	1	1	70	1	5	78

Table 46f

The results of "Periodontal Pocketing at One Year"

	Periodontal Pocketing CPITN at One Year						
Classes	1	2	3	N	(blank)	Patient Absent	Total
Frequencies	64	2	4	2	1	5	78

For the measurement "Sinus at One Year" an exception was made in that a two-way table with "Blanks" and "Absent Patients" (column) removed, was constructed.

Table 47

The results of "Sinus at One Year"

		Sinus at One Year		
Failure or Success		No	Yes	Total
Failure	Frequency	3	6	9
	Row Percentage	33%	67%	100%
Success	Frequency	60	2	62
	Row Percentage	97%	3%	100%

The proportion of "Sinus at One Year" was much more in the "Failure" group compared to than of the "Success" group ($p<0.001$). The existence of a sinus would normally be apportioned as a failed root treatment, but in the two cases cited here, the sinus was present due to the presence of a furcation lesion (possible presence of a crack in one case). The two cases of "sinus present" in the "success" group were considered successful due to their otherwise symptomless features and continued function in the mouth. The true estimates of the row proportions could not be affected greatly by the "Absent Patients".

Table 48

The results of "Coronal Restoration at One Year"

	Coronal Restoration at One Year				
Classes	No	Yes	(blank)	Patient Absent	Total
Frequencies	16	55	1	6	78

Concluding Remarks on the Statistical Analysis

Of the 81 initial teeth in this study, 43 were evaluated at One and Four Months and also at One Year. Three teeth have not been evaluated at any of the follow-up visits. Twenty-eight of the root canal treatments were evaluated at two of the three follow-up visits, and seven were evaluated only at one of the three visits. Three of the 81 initial teeth were not classified as a "Success" or "Failure" and could therefore not be part of the main analysis.

The definition of "Failures" is not pure (some cases that have failed may be due to a cyst and not to root treatment failing). However, reducing the number of "Failures of the Root Treatment" will make it more difficult to identify factors influencing "Failure", due to the loss of statistical power. Missing values (or "Patients Absent") hinders the ability to identify (evaluate) factors that can influence the "Success" or "Failure" of Root Canal Treatment.

The table below summarises those factors which are, or not, statistically significant. It also includes factors that are not proven either way due to the low number of presenting cases or when the factors were for comparative purposes only.

FACTORS	SIGNIFICANT	NOT SIGNIFICANT	Could not prove either way
age			YES
sex		YES	
pain		YES	
quadrant		YES	
position			YES
mobility		YES	
TTP		YES	
CPITN	YES		
sinus	YES		
abutment/crown		YES	
occlusion	YES		
history of trauma		YES	
tooth crack			YES
apical rarefaction	YES		
diffuse/well defined	YES		
post present	YES		
presence of apicectomy			YES
Crown/root ratio		YES	
External resorption			YES
length of roots	YES		
complexity of anatomy		YES	
leaking coronal restoration		YES	
bone-loss			YES
obturation to WL	YES		
obturation short	YES		
overextension			YES
un-located canals		YES	
silverpoints			YES
separated instruments			YES
n2 paste			YES
ledges		YES	
k3 files		YES	
protaper		YES	

accessory/lateral canals		YES	
final obturation to WL		YES	
final obturation short		YES	
final obturation overextended			YES
final post bonded	YES		
composite core	YES		
bonded amalgam core		YES	
microscope			YES
interception times		YES	
one or multiple appointments		YES	
inter-appointment medications			YES
diminished rarefaction		YES	
post pain	YES		
mobility at one month			YES
TTP at one month			YES
CPITN at one month			YES
sinus at one month			YES
coronal restoration at one month			YES
extracted at one month			YES
diminished rarefaction at four months			YES
pain at four months			YES
mobility at four months			YES
TTP at four months			YES
CPITN at four months			YES
sinus at four months			YES
coronal restoration at four months			YES
extracted at four months			YES
diminished rarefaction at one year			YES
sinus at one year	YES		

Chapter 3

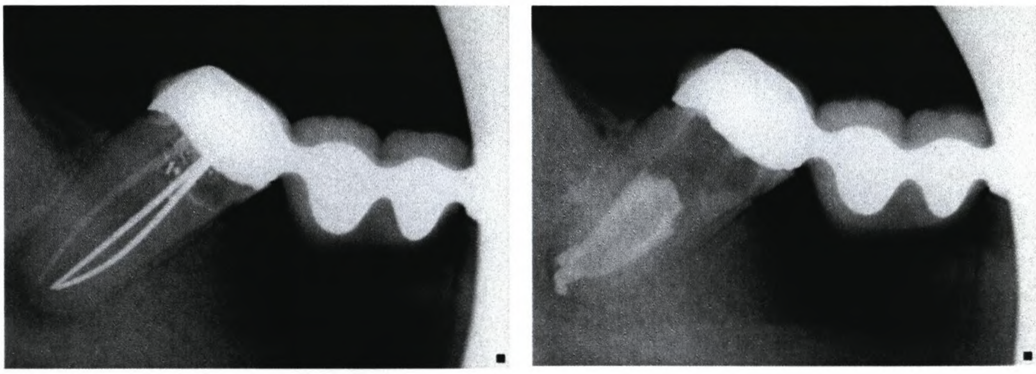
Discussion

The literature review introduced criteria that would allow for an objective description of the success or failure of root treatments. Currently it is favourable and accepted to complete the description with a subjective and clinical appraisal. The subjectivity would include the patient's expectations which might be the functionality of the tooth in question. So success can be measured by the goal/s that were established at the outset or agreed upon during the retreatment. The usual goals with regard to endodontic therapy, is to prevent or heal apical periodontitis. Because healing is a dynamic process and may take a number of months or years to resolve, the clinician's appraisal may describe the clinical presentation as "healing in progress". Disease presented radiographically may still present with normal clinical signs and the patient may still be able to retain the tooth for a period of time. Thus the specific goal set out by the individual patient may either be healing/prevention of disease (apical periodontitis) or just functional retention of the tooth. Therefore when reviewing the tooth, the individual's set specific goals for treatment must be evaluated and the outcome seen in relation to that goal.

Teeth without apical periodontitis, after initial treatment or orthograde retreatment are 92% to 98% successful. The chance of teeth with pre-existing lesions to completely heal after initial treatment or retreatment is 74% to 86%, and their chance to be functional over time is approximately 91% to 97% (Friedman S and Mor C, 2004). Thus there does not appear to be a great difference in outcome between initial treatment and orthograde retreatment. Interestingly the outcome of treatment is not significantly different from the earlier studies reviewed in the literature review. Considering the favourable outcome, conservative retreatment endodontic therapy, is justified and should be attempted when a good restorative and periodontal prognosis is projected, unless the patient is not motivated to retain the tooth.

A case must be considered to have failed if adverse clinical signs and symptoms persist. The converse is not true and the absence of signs and symptoms cannot be correlated with the absence of pathology. In fact, pathological change, without significant symptoms, is common. In the current study the number of cases that were deemed successful was 87% with 7.8% were failures. A number of the failures may be due to the presence of cysts or cracked root related to the teeth but not a cause of the failure of the root treatment and thus the number of root canal retreatment failures described are actually further reduced. Therefore the correct diagnosis of a "failing" root treatment cannot be overemphasised when planning the "correct" treatment plan (Ruddle CJ, 2003a).

Before a decision is made to retreat, it is essential to relate the failure to a specific cause. The feasibility of successfully retreating a failed case depends on the elimination of the cause of failure. Practical considerations before retreatment is initiated are firstly to gain access and carefully determine the correct orientation and tilt of the coronal portion and note for any iatrogenic mishaps. After access has been gained, posts may be encountered and then must be removed. After post removal it is necessary to negotiate to the apex. The most frequently encountered filling materials in retreatments are pastes and cements, gutta percha or solid materials, such as silver points and fractured instruments. Also carrier based gutta percha systems introduce additional challenges in endodontic retreatment. Removing metal fragments such as separated files is one of the most demanding procedures and requires special knowledge of techniques, the use of special technologies and much patience and obstinate endurance. Nowadays retreatment can approach 100 percent success, and so should be considered even under the appearance of difficult teeth (Ruddle CJ, 1997a; Niemczyk SP, (2003); Ruddle CJ, 2003b; Fleming PS and Dermody J, 2004).



Above is an example of a retreated case involving the removal of silver points, obturated with gutta percha and its successful outcome.

Strindberg's system of evaluating whether root treatment has been successful or not represents a clear definition of disease, which means, that it is limited and made explicit by a formal definition; not all our concepts are defined in such a precise way, yet we say that these concepts exist. They exist in the sense that people use them. Such concepts are named "praxis concepts". A periapical health continuum is the basis of a praxis concept. Various periapical conditions may be perceived as different stages on a continuous health scale, based on their radiographic appearance (Reit C and Kvist T, 1998; Kvist T, 2001).

With regard to the above concept, the decision to carry out endodontic retreatment should not be made lightly and requires an assessment of the risks and benefits involved. If the patient is asymptomatic but a pathological condition is present, a determination must be made to observe or to retreat. A decision to monitor may seem tempting to the patient who is asymptomatic, but one must consider that failing, though asymptomatic, root filled teeth may result in acute flare-ups and may make eventual treatment more difficult as often it has to be done through a coronal restoration. Should a decision be made to retreat the case, the options are non-surgical retreatment, surgical treatment, a combination of the two or extraction. A number of factors must be considered in making this decision. In addition to the results of a very thorough assessment of the tooth involved, one must take into account the remaining dentition, patient motivation, oral hygiene, age, probability of success and cost.

Where inadequate endodontic treatment is present, but there is no evidence of pathology, the dilemma is more acute. It is impossible to predict whether or not a poorly completed case will fail at some point in time. It is considered acceptable to observe questionable endodontic therapy that is not failing, unless the involved tooth requires a new restoration or is to function as a critical abutment in a restorative treatment plan (Rafter M, 2003). Each dentist must recognize where they "fit in" on the periapical health continuum – when do they intervene or not? It is almost like an individuals' philosophy about treatment: when to treat or not to treat? The dentist must self evaluate why they would choose to treat or not and when they would intervene by means of retreatment.

Rawski *et al*, (2003) looked at the major reasons to retreat when faced with a root filled tooth with an associated periapical rarefaction. Retreatment procedures were suggested more often by the endodontists who took part in the research than by general dentists. A non-surgical approach was almost always suggested by endodontists and general dentists, except when an overfill was present. The majority of dentists interviewed thought there was no problem in deciding whether there was a need for retreatment or not, unless the area was of a small size. The factors that were expressed when assessing the cases were: "the future treatment scheme, periapical disease, size of bone destruction, quality of seal, age of seal, retreatment easy to perform, prognosis, economy, overfill and patient's preference for treatment".

Retreatment decisions were found to be subject to substantial intra-individual variation over time and for non-rational reasons. The variations may reflect changes in attitude towards retreatment. Recent technical developments (surgical microscopes, ultrasonic retrotips, new root-end filling materials, nickel-titanium instruments, rotary systems) and reconsidered retreatment strategies have changed the scope of retreatment and consequently may exert an influence on decision making (Kvist T and Reit C, 2002; Niemczyk SP, 2003).

General practitioners chose to initiate treatment at an earlier date and also chose more extensive treatment modalities than endodontic postgraduates (Pagonis *et al*, 2000). The larger the size of the periapical lesion was an important factor when deciding whether to retreat or not (Kvist *et al*, 1994).

The current study included all referrals for retreatment, no cases were excluded from the study unless the treatment plan offered and included surgical correction or the use of materials, such as, MTA. The current study cannot give any information of those cases ***not*** referred by the general dentists. The general dentists might have excluded referrals that they deemed hopeless, or not worth trying to save as other options might give better prognoses (such as, implants).

Hoen MM and Pink FE, (2002), conducted a prospective in vivo study to determine radiographic and clinical factors associated with non-surgical endodontic retreatments. It was anticipated that an evaluation of why the retreatments were necessary would lead to recommendations that might improve the rate of clinical success. This was not the case. Therefore one cannot determine which cases would be successful or not, depending upon how the particular case presented. A significant number of "endodontic failures" were subsequently extracted due to the patients' desire, extensive recurrent caries, severe periodontal disease, vertical root fractures, extensive resorption, or irreparable iatrogenic misadventures.

In most instances in the current study, it was not possible to accurately determine the number of months or years that the preceding endodontic treatment was completed. The presence of pain was determined subjectively by questioning the patient. No distinction was made to identify frequency, duration, cause, or intensity of pain. The presence of pain was determined objectively by noting clinical responses to palpation of the periradicular tissues, percussion, bite testing, and when applicable, thermal testing of the tooth (in cases of suspected missed canals). Clinical treatment also confirmed the type of filling material and further identified instances of coronal leakage. The statistically significantly high degree of correlation between an asymmetrical obturation in the initial preop x-rays and the ability to locate additional canal space seems clinically relevant.

A study by Kvist T and Reit C (1999), of randomised selection of failed root treatment retreated by non-surgical or surgical approach failed to show difference in the outcome. However, the healing pattern seems to differ between the two groups. Surgical retreatment seems to result in a more rapid periapical bone fill. Findings suggest a higher risk of "late failures" on the other hand. Thus from a scientific point of view, the length of follow-up period is imperative and may strongly influence the conclusion made. The validity of conclusions drawn in the study might change due to the benefit of microscopes, ultrasonic tips and rotary NiTi files that are currently available. When making a decision of surgical verse non-surgical correction it must be noted that surgical retreatment resulted in more discomfort and tended to bring about greater indirect costs than non-surgical retreatment (Kvist T and Reit C, 2000).

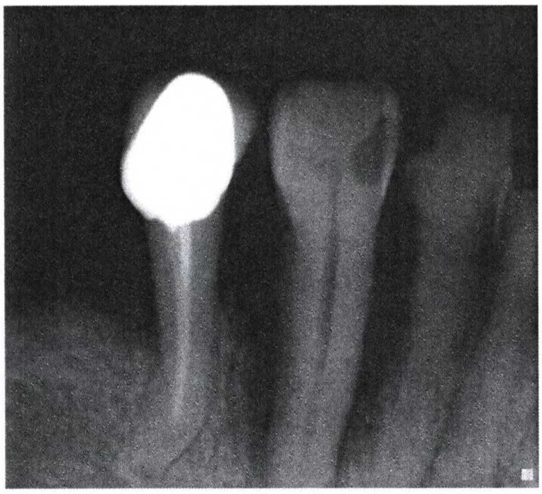
The causes of endodontic failure include coronal leakage, fractures, post errors as a result of diameter, length and direction, missed canals, short fills, overextensions with internal underfilling, blockages, ledges, perforations, canal transportations, broken instruments and hopelessly involved periodontal teeth. Regardless of specific cause, the sum of all causes is leakage and endodontic failure. When confronted with endodontic failure, clinicians must select the best treatment approach to provide long-term predictable success (Ruddle CJ, 1997b; and Gorni FJM, 2002).

The cases in the current study that presented with sinus draining were found to have a poorer prognosis. The two estimated proportions of "Sinus" present (60%) in the "Failure" group and 10% in the "Success" group were significantly different ($p<0.01$). The presence of a sinus after retreatment leads to the diagnosis of a failed root treatment. An alternative differential diagnosis of the cause of a sinus might be from the presence of an undetected cracked root or cyst rather than from a failed root treatment.

In the current study there was a statistically significant result of no pain experienced in patients in successful outcome of retreatment cases (between 5% and 10%) after the first month review.

The CPITN scoring was statistically significant, in 40% of cases with failed results and 13% in the "Success" group ($p<0.10$). This is consistent with the literature reviewed articles as the function and periodontal attachment levels have an influence on the mobility and attachment of the root and exposure of the dentinal tubules. The increased mobility of the tooth may impact on the reduced apical healing (Matsumoto *et al*, (1987), Storms JL, (1969) and Lin *et al*, (1992).

In the current study there was a significant difference between the "Failure" and "Success" groups (Fisher Exact Test, $p<0.05$) with regard to teeth that presented with initial short root fillings that contributed to the final success of retreatment. The current study showed no statistically significant differences in the final retreatment between cases that had short or underextended fills in those that were successful or failed. This may be due to the extended effort in trying to attain correct working length but not being successful. The conclusion drawn from those cases is that the apical extent that was not filled was impossible to do so in the clinical setting. In the current study, when the initial root treated teeth had initial underextended root canal fillings they were mostly found to be due to the canal having been ledged. The retreatment preparation in the current study had to include managing these ledges first.



The above left x-ray shows the initial presentation of a short or under-extended root filling. The second x-ray shows the correct length, after the ledge was managed.

Often short or underextended root fillings contributed to failures and consequently longer root lengths also provided more failures (Wilcoxon Rank Sum Test, p-value = 0.0628). Longer root length roots tend to be not as clean as shorter roots for obvious reasons of not reaching the full length of the root canals when cleaning and shaping.

It was found that this current study corroborated with many previous studies that the larger pretreatment apical rarefaction had a direct influence on the success or failure of the retreated tooth (Sjögren *et al*, (1990). The current study showed that areas below 6mm diameter had more chance of successful outcome. The prognosis in the current study indicated that the description comparing well defined or diffuse lesions did have an influence in the outcome of the retreatment results (as opposed to the study by Storms JL, 1969) and specifically showed that "diffuse" lesions healed statistically more often ($p<0.001$). Well-defined lesions may have a condensed border that may require more time to break down and recreate a healthier alveolar architecture. The current study was only carried over one year and previous studies have shown that the successful outcome increased over time (Bender *et al*, 1966a; Harty *et al*, 1970; and Adenubi JO and Rule DC, 1976).

Post placement (Fisher's Exact Test $p<0.01$) and core build up immediately following retreatment in the current study demonstrated a greater chance of success for the tooth (Fisher's Exact Test $p<0.0001$). This must be due to the coronal seal eliminating any bacterial seepage down the root canal. It must be noted that posts were only placed into the roots when there was sufficient coronal dentine (ferrule) to help support the post from debonding (Ferrari *et al*, 2000).

The current study also compared retreatment using two different file systems, ProTaper (PT) and K3. Di Lenarda *et al*, (2004) demonstrated that Profiles as compared to GT (progressive taper) rotary files produced more apical modifications. Over the last two decades there have been many new NiTi rotary systems introduced on the market which proclaim their advantage over other systems (Baumann MA, 2003; Buchanan LS, 1996; Koch K and Brave D, 2003), but with little scientific backing. Nahmias Y and Serota KS, (2003) describe the hybrid approach of two rotary systems (ProTaper and GT) in order to gain the benefits of both system and combine them in root canal preparation.

In the current study most cases were finished with file tip size 25# in either system (38-K3; 30-PT); size 30# (7-K3; 5-PT); size 20# (2-PT) and 40# and 60# (1-PT and 1-K3). It has been found that the determination of the apical diameter can be misinterpreted with the use of tapered files due to the "binding" in a more coronal position of the files. This may mislead the clinician in choosing a file with a smaller diameter that will shape the apical extent of the canal. The enlargement of the apex with the use of files that have a diameter of 0.3 to 0.4mm with a non-tapered file will enable better cleaning of the root canal, mechanically and chemically and will ensure removal of more microorganisms, thus improving the overall success of the treatment (Kfir A *et al,* 2006). In the current study the file tip size did not show any affect on the outcome.

The current study was made using two different types of NiTi file systems: ProTaper and K3. They were chosen because they are popular systems on the market currently and they are good examples of variable/progressive taper

(ProTaper) and constant tapered files (K3). The current study was to determine factors that might influence the prognosis of non-surgical retreatment, so it was worthwhile comparing results of these two systems.

Both file systems work well in the hands of an operator who understands their limitations and has respect for canal anatomy and metal properties of the files. The operator in the current study did not rely on an electrical hand-piece with torque control, but used a slow reducing hand-piece (70:1).

The current study indicated that there was no statistical advantage of one file system over the other with regard to the success outcome. It appears from the literature (Bergmans *et al*, 2003; Schafer E and Vlassis M, 2004; Ankrum *et al*, 2004; Iqbal *et al*, 2004; Yang *et al*, 2006; Saad *et al*, 2007) that when comparing the shaping ability of variable/progressive (ProTaper) versus constant taper (Hero 642, RaCe, K3 or Profile), shaft designed instruments in simulated root canals, Hero 642 and RaCe systems prepared canals more rapidly and maintained working length significantly more accurately than ProTaper instruments. In canals prepared with Hero 642 and compared to K3 instruments, there was less change in curvature. Instrumentation with ProTaper results in transportation towards the outer aspect of the L-shaped curved canals in the apical part and the inner aspect of the S-shaped canals at the curve. Hero 642 and K3 instruments had a better centring ability in the apical part of the canal, but resulted in shapes with a poor taper. However, both ProTaper and Hero 642 instruments prepared curved canals rapidly, maintained working length well and were relatively safe without creating perforations and danger zones. There is no difference between the two systems (ProTaper and Hero 642) for the time needed to remove gutta percha from a root canal (research done before specific retreatment files were marketed).

A study by Ankrum *et al*, (2004), compared the torsional qualities of various rotary files and found that the proportion of files distorted was 15.3% for the ProFile group, 2.4% for the ProTaper group, and 8.3% for the K3 Endo group. There was a statistically significant difference between the ProFile and ProTaper groups. They also compared the number of files that separated during instrumentation with the various file systems and found that the percentage of broken files was 1.7% for the ProFile group, 6.0% for the ProTaper group, and 2.1% for the K3 Endo group. No statistically significant differences were found between these three groups. Shen *et al*, (2006) also compared the incidence of instrument separation. 14% of ProTaper resulted in file breakage, as compared to 7% in Profile. The proportion of unwinding defects was 5% in ProFile and 0.3% in ProTaper instruments. Therefore it indicated that while ProTaper was more likely to separate without warning, ProFile tended to exhibit unwinding of flutes more frequently. In the current study the "Successes" with K3 File (35 out of 41) was 85% and with Protaper File (32 out of 36) was 89%. The "Success" rate certainly was not different between the two file types.

It would be worthwhile, in the clinical setting, to examine the flutes after every exit of the file from the canal it was working and discard those that showed signs of unwinding (Guettier P, 2003).

Conclusion

Often factors associated with root canal treatment failures are multivariate and therefore a number of factors were included in the current study.

The factors that may influence the prognosis in non-surgical retreatment studied included, were:
Age of patient, sex of patient, tooth, pain experienced, mobility, periodontal attachment, tender to percussion (TTP), sinus present, abutment/crown, occlusion, history of trauma, cracks, size of apical rarefaction, description of lesion: diffuse/well-defined, post present, signs of apicoectomy, crown/root ratio, external resorption, length of roots, complexity of anatomy, leaking coronal restoration, bone-loss, furcation, initial working length correct or underextended or overextended, unlocated canals, silver points, separated instruments, perforations, n2 pastes, ledges, K3 (constant 06 taper), ProTaper (variable/progressive taper), final working length correct or underextended or

overextended, accessory canals, post bonded, core, single/multiple appointments, cysts present and time intervals to review the healing progression after 1 and 4 months interval and after 1 year.

The following conclusions were drawn from the research:
The current study showed that the overall success rate was 87% or 7.8% were failures. Successful results were influenced by the initial absence of periodontal pockets, a description of a diffuse pretreatment lesion, the size of the preoperative lesion (less than 6mm diameter), short root fillings in the initial root treated tooth, a correct and optimally retreated and obturated canal to working length, teeth in occlusion, and a good coronal seal by means of an immediate post and core filling.

The current study agreed with the reviewed literature that the following factors did not have any influence on the prognosis: sex or age of the patient. The low number of failures in the study did not allow the statistics to prove whether various signs would influence the prognosis or not. They are: pain and TTP. There was no evidence in the current study that overextensions, or short root fillings in retreatments, the crown/root ratio, complex anatomy or apical resorptions and the position of the tooth in the mouth or the quadrant in which the tooth was treated and the mobility of the tooth would have an effect on the outcome of the treatment. The current study could not indicate whether the number of appointments to treat would influence the results. The current study showed that the different file systems used or master file tip size did not contribute or influence results and therefore cannot be implicated as a factor that might influence results in non-surgical endodontic retreatment.

Failure was often attributed to the presence of a sinus or crack in the root but this fact could not be verified in the current study. It was found that post-operative pain would indicate a greater chance that the retreatment would not be successful. Longer roots (than the Median) were implicated in failed retreated teeth.

The current study reviewed the healing process over a period of one year with checks at 1 month and 4 months. It was found that the tooth's success could be gauged usually after 4 months.

Retreatment may offer a very good option when faced with a failing or failed root treatment. Currently, clinicians can offer a high rate of success for retreatment when armed with necessary knowledge of the complex anatomy of the root canal system, knowledge to deal with obstacles that may complicate retreatment and knowledge to combat the biological reasons of failure.

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Questionnaire to accompany research on the clinical study to determine factors that may influence results in non-surgical endodontics.

	1	2	3	4	5	6	7	8	9	10	11	12
patient	D0001 4	Mh000 5	MH00 05	C0004 0	D00016	ST0003 0	ST000 36	D00010 6	D0001 06	MC	C00084	St00088
General characteristics												
age	1970	1956	1956	1964	1958	1931	1951	1953	1953	1943	1959	1969
Sex	M	M	M	F	F	F	F	F	F	F	M	F
Pain	X	X	X	X	X	X	X	X	X	X	X	X
Tooth	47	46	45	26	34	15	46	14	34	15	26	36
mobility	X	X	X	X	2	1	X	X	X	X	X	X
TTP	X	X	X	X	1Y	X	X	X	X	X	X	X
Periodontal pocketing CPITN	1	1	1	1	3	1	1	1	1	1	1	1
Sinus	X	Y	X	X	X	X	X	X	Y	X	X	X
Abutment	X	X	Y	X	X	Y	Y	Y	Y	Y	X	Y
Occlusion	Y	X	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
history of trauma	X	X	X	X	X	X	X	X	X	X	X	X
Tooth cracked	X	X	X	X	X	X	X	X	X	X	X	X
Specific tooth characteristics												
Apical rarefaction (mm)	12,2	8,8	0	3,6	4,8	3,5	1,4	5	7,8	9,2	0	0
Diffuse/**W**ell-defined	D	D		D	D	W	D	D	D	W		
Post present (mm to apex)	X	X	X	X	X	X	9,2	X	7,9	9	X	X
Presence of apicectomy	X	X	X	X	X	X	X	X	X	X	X	X
Crown/root ratio	9,8/11, 7	5,5/14, 9	6,7/16, 7	8,5/13, 5	11,3/11 ,5	7,8/11,7	7/10,8	10,2/10 ,4	8,6/13, 6	7,8/11, 7	7,6/17,7	7,5/17,9
External resorption	X	X	X	X	X	X	X	X	X	X	X	X
Length of roots (mm)	21,6	20,5	23,5	21	22,8	18,2	19,4	20,2	22,1	19,3	25,4	24,2
Complexity of anatomy of roots (curved)	X	Y	X	Y	X	X	X	X	X	X	Y	Y
Leaking coronal restoration	X	Y	X	X	X	X	X	X	X	X	X	X
Furcation boneloss (mm)	X	X	X	X	X	X	X	X	X	X	X	X
Boneloss involving one root (mm to enamel)	X	X	X	X	9,2	4,7	X	X	X	X	X	X
Boneloss involving two roots (mm to enamel)	X	X	X	X	X	X	X	X	X	X		X

ANK (appointment not kept)

patient	1	2	3	4	5	6	7	8	9	10	11	12
Previous failing root treatment characteristics												
Obturation to WL	X	Y	X	X	Y	X	X	X	Y	X	Y/X	X
Obturation short (mm)	4	X	4	3	X	2,7	6,3	1,6	X	2.9	2	17
Overextension (mm)	X	X	X	X	X	X	X	X	X	X	X	X
Unlocated canal/s	Y	Y	X	Y	Y	X	Y	X	X	Y	X	X
Silverpoint failing	X	X	X	X	X	X	X	X	X	X	X	X
Broken instruments (apical, mid-root)	X	X	X	X	X	X	X	X	X	X	X	Y
Perforation (size, position, time)	X	X	X	X	X	X	X	X	X	X	X	X
N2 paste	X	X	X	Y	X	X	X	X	X	X	X	X
ledges	X	Y	Y	Y	X	Y	Y	X	X	Y	X	X
Final retreatment characteristics												
K3 files	X7/12/4	25	25	X	X14/12/4	2515/12/4	25	25	25	25	X14/2/5	X17/3/5
Protaper	25	X12/11/4	X12/11/4	20/25	25	X	X22/12/4	X10/5/5	X21/6/5	X10/1/5	25	25
Accessory/lateral canals	Y	X	X	X	Y	X	X	Y	X	Y	X	X
Obturation to WL	Y	Y/X	Y	X	Y	Y	Y	Y	Y	Y	Y	Y
Obturation short (mm)	X	4	X	1,6	X	X	X	X	X	X	X/1,8	X
Overextension (mm)	X	X	X	X	X	X	X	X	X	X	X	X
Post bonded	X	X	X	X	X	Y	Y	X	Y	X	X	X
Composite core	X17/1/6	X	X	X	X	Y	Y	Y	X	X	X	Y
Bonded amalgam core	X	X	X	X	X	X	X	X	X	X	Y	X
Microscope	X	X	X	X	X	X	X	X	X	X	X	Y
Interception times (months)	?	?	?	?	?	?	?	?	?	?	?	3
One/multiple appointments	1	1	1	1	1	1	2	1	1	1	1	1
Inter-appointment medications	X	X	X	X	X	X	X	X	X	X	X	X

patient	1	2	3	4	5	6	7	8	9	10	11	12
Follow up appointments												
1 month												
Diminished rarefaction Y or X/date	Y1/3/5	Y10/12/4	X10/12/4	Y17/1/5	Y18/1/5	X20/1/5	Y12/1/5	ANK	ANK	Y14/3/5	ANK	ANK
pain	X	X	X	X	X	X	X	ANK	ANK	X	ANK	ANK
mobility	X	X	X	X	2	X	X	ANK	ANK	X	ANK	ANK
TTP	X	X	X	X	1	X	X	ANK	ANK	X	ANK	ANK
Periodontal pocketing CPITN	1	1	1	1	1	1	1	ANK	ANK	1	ANK	ANK
Sinus	X	X	X	X	X	X	X	ANK	ANK	X	ANK	ANK
Coronal restoration	X	X	X	X	X	Y	X	ANK	ANK	X	ANK	ANK
extracted	X	X	X	X	X	X	X	ANK	ANK	X	ANK	ANK
4 months												
Diminished rarefaction Y or X/date	Y21/6/5	X4/3/5	X4/3/5	Y11/4/5	Y15/5/5	Y4/5/5	ANK	Y10/1/6	Y10/1/6	Y31/8/5	X	X
pain	X	X	X	X	X	X	ANK	X	X	X	Y6/6/5	X
mobility	X	X	X	X	1	X	ANK	X	X	X	X	X
TTP	X	X	X	X	X	X	ANK	X	X	X	X	X
Periodontal pocketing CPITN	1	1	1	1	2	1	ANK	1	1	1	1	1
Sinus	X	Y	X	X	X	X	ANK	X	X	X	X	X
Coronal restoration	X	X	Y	X	X	Y	ANK	Y	Y	X	X	X
extracted	X	X	X	X	X	X	ANK	X	X	X	X	Y
1 year												
Diminished rarefaction(mm) Y or X/date	0Y 17/1/6	0,2Y 12/5/6	0Y 12/5/6	0Y 9/2/6	0,8Y 7/2/6	0,8Y 2/2/6	0Y 30/3/6	0,4Y 16/5/6	0Y 16/5/6	0Y 8/3/6	0Y 5/4/6	0X 2/2/6
pain	X	X	X	X	X	X	X	X	X	X	X	X
mobility	X	X	X	X	X	X	X	X	X	X	X	X
TTP	X	X	X	X	X	X	X	X	X	X	X	X
Periodontal pocketing CPITN	1	1	1	furcation	1	3	1	1X	1	1	1	1
Sinus	X	Y	X	Y	X	X	X	X	X	X	X	X
Coronal restoration	Y	X	Y	Y	X	Y	X	Y	Y	Y	X	X
SUCESS/FAILURE/UNSURE	S	F	S	S	S	S	S	S	S	S	S	S