Chapter 1

GENERAL INTRODUCTION

Although the dental pulp has a large regenerative capacity, it is not resistant to carious processes and other injuries. This may result in a limited inflammatory response or complete necrotic deterioration. Once the pulp has necrotised, the root canal represents a unique and stringent ecological niche for bacterial growth due to lack of oxygen and the availability of host tissue and tissue fluids as primary nutrient sources (Sundqvist 1992). Pulpal necrosis allows colonisation and growth of microorganisms resulting in an inflammatory response in the tissues surrounding the root apex (Kakehashi et al. 1965, Möller 1966, Sundqvist et al. 1979). This condition is called apical periodontitis.

Apical periodontitis results in bone loss around the root tip, which is manifest on radiographs as a periapical radiolucency. The prevalence of periapical radiolucencies in dentulous individuals is 40-60 % (Eriksen et al. 1988, Ödesjö et al. 1990, Eriksen & Bjertness 1991, De Cleen et al. 1993). This indicates that apical periodontitis is a frequently occurring disease. The distribution in the population shows a higher risk of apical periodontitis in older age groups (>40 years) (Eriksen 1991). In the latter age group, 5-8% of the remaining teeth are affected (Eriksen 1998).

Local defence mechanisms of the tissues around the root cannot control the microorganisms within the pulp space. Therefore, elimination by mechanical and chemical intervention is essential to control the disease. Root canal treatment or extraction of the tooth can accomplish this.

Bacteria are not only located in the necrotic pulp tissue but adhere to the root canal wall, are present in the dentinal tubules (for an extensive review see chapter 2) and can occur in periapical plaque on the root surface (Tronstad et al. 1987, Siqueira & Lopes 2001).

To induce peri-apical healing, removal of microorganisms from the root canal system and prevention of reinfection is essential. Treatment of apical periodontitis involves three essential components:

- Mechanical instrumentation
- Irrigation and chemical disinfection
- Obturation of the pulp cavity

If these procedures are carried out properly a high success rate, with complete resolution of periapical periodontitis, can be expected. Well-controlled studies, based on radiographic evaluation, report success rates
of 83-94% (Strindberg 1956, Byström et al. 1987, Sjögren et al. 1990). Lower success rates of 60-77% are generally found in epidemiological studies as reviewed by Eriksen (1998).

**Mechanical instrumentation**
The objective of mechanical instrumentation is to remove the main bulk of infected material and its nutritional supply.

The procedure aims:
- To physically remove as much as possible of bacterial mass.
- To remove sources of substrate for bacterial regrowth and multiplication including necrotic tissue and tissue-breakdown products.
- To remove the inner portion of the root canal wall where dentine is most heavily infected.
- To provide access for irrigation solutions to all parts of the root canal system for cleaning and chemical disinfection.
- To create a clean and properly shaped canal that facilitates the insertion of a well-sealing root canal filling.

It may be very complicated to successfully reach these objectives. Microorganisms are not only located in the main canal, but they will also enter any space and ramification available including isthmuses, dentinal tubules and lateral canals (Oguntebi 1994, Weiger et al. 2001). It needs to be recognised that crevices and lateral areas of oval shaped canals are especially difficult to reach with root canal instruments (Walton 1976, Evans et al. 2001, Wu et al. 2001, Wu & Wesselink 2001). If untouched by instruments both substrate and bacterial organisms may remain in such locations. When a pathway to the apical environment is available, periapical inflammation may remain.

**Irrigation and chemical disinfection**
Mechanical instrumentation of root canals needs to be supported by frequent irrigation. An important goal of irrigation is the removal of debris and dentinal shavings. Another is to keep canal(s) moist so instrumentation can run smoothly. It is also considered critical that the irrigation solution should exert bactericidal effects. In clinical trials, bacteria were frequently recovered from teeth treated with mechanical instrumentation and water irrigation alone (Byström & Sundqvist 1981). To augment the efficacy of the instrumentation procedure an irrigating solution for root canals should also be able to dissolve necrotic tissue remnants especially in areas where mechanical instrumentation cannot reach, including crevices, invaginations and lateral canals. Finally the agent should cause minimal tissue damage and thus be minimally reactive in case it is extruded into the peri-
apical tissue environment (Spangberg et al. 1979).
The most commonly recommended and employed solution for endodontic irrigation is sodium hypochlorite (NaOCl). Sodium hypochlorite unites three important qualities essential to root canal treatment,
-It dissolves organic material
-It is a potent disinfectant
-It is minimally tissue irritating in low concentrations.
The tissue-dissolving capacity of NaOCl is well established (Hand et al. 1978, Moorer & Wesselink 1982). Both vital and necrotic tissues are affected and dissolved by NaOCl. It is a strong and fast-acting disinfectant with a low tissue irritating potential. The latter applies only to concentrations lower than 1%, while it is a potent tissue irritant in higher concentrations (2.5-5%) (Lamers et al. 1980, Harrison et al. 1981, Rosenfeld et al. 1978). High concentrations are therefore avoided or used with great care so that no solution is extruded beyond the apical foramen, which may cause a severe tissue irritation.
The risk-effectiveness of the use of high concentrations of NaOCl can further be questioned based on limited gain in antibacterial effect found in clinical trails (Byström and Sundqvist 1985). On the other hand, higher concentrations may have better tissue dissolving capacity (Hand et al. 1978).
The most frequently recommended and most commonly used concentration is a compromise, 1-2%. This concentration still has a good necrotic tissue dissolving and antibacterial capacity (Moorer & Wesselink 1982, Byström & Sundqvist 1985, Baumgartner & Cuenin 1992). After instrumentation and irrigation with NaOCl, approximately 50-80% of root canals is free of cultivable microorganisms (Sjögren & Sundqvist 1987, Shuping et al. 2000). The number of microorganisms that are not removed from the root canal after instrumentation and irrigation are low (Byström & Sundqvist 1981, Sjögren & Sundqvist 1987, Shuping et al. 2000). Yet, if given space and nutrition, re-growth into original numbers may soon occur.

In principle, there are two approaches to control the residual microorganisms.
1- enhance bacterial elimination before the permanent root filling by applying a disinfectant in the instrumented canal between two treatment sessions (intracanal disinfectant).
2- entomb the residual bacteria in the permanently filled root canal space. Root filling is then carried out after the completion of the biomechanical preparation in the same visit.

Inclusion of an intracanal disinfectant
A multitude of anti-microbial agents has been used in the past to serve as
an interappointment canal disinfectant (Chong & Pitt Ford 1992). In recent years, a water slurry of calcium hydroxide (CaOH\(_2\)) has gained considerable acceptance as an interappointment disinfectant in endodontic therapies (Chong & Pitt Ford 1992, Fava & Saunders 1999). It is an alkaline substance (pH = 12.5) that dissociates in calcium and hydroxyl ions when it interacts with fluid. The latter property results in antimicrobial and tissue dissolving ability (Bystrom et al. 1985, Hasselgren et al. 1988, Georgopoulou et al. 1993, Siqueira & Lopes 1999). Because of its low solubility, it holds up in the endodontic space over long periods to prevent bacterial regrowth. The antibacterial capacity of calcium hydroxide however, is limited to the microorganisms in the near vicinity. It does not effectively kill bacteria in non-instrumented parts of the canal and in the dentinal tubules (Ørstavik & Haapasalo 1990).

**Obturation of the root canal with a permanent root canal filling**

Entombing the residual bacteria by obturation of the root canal system with a permanent root canal filling, immediately after cleaning and shaping of the pulp space, may deprive them from nutrition. In addition, root canal sealers that are used during obturation posses antibacterial properties before they set (Fuss et al. 2000). It is speculated that the residual bacteria may receive nutrition when the coronal seal is broken. This will enable them to regrow and cause new periapical pathology when a pathway to the periapical tissues is available. However, when coronal leakage occurs microorganisms from the oral cavity will also be able to reach the root canal space. These bacteria will outnumber the residual bacteria.

**SCOPE AND OUTLINE OF THE THESIS**

It is clear that microorganisms in the necrotic pulp tissue are the cause of apical periodontitis and that their removal by root canal treatment will result in healing in most instances. However, with contemporary means it is impossible to remove all microorganisms from the root canal system. A common opinion how to deal with these remaining bacteria after root canal instrumentation and irrigation does not exist. This issue forms the continuous thread through this thesis. Since in the literature an increasing interest in mechanisms how to kill microorganisms remaining in the dentinal tubules was shown it was considered necessary as a first approach to review the literature to evaluate the existing knowledge about the presence, role and fate of microorganisms in the root dentinal tubules (chapter 2). The first experiments in chapter 3 were conducted to develop an *in-vitro* model that can be used to study the
effects of several treatment modalities. The dentine specimen and microorganisms are surrounded by nutrients and it is possible to measure the number of microorganisms that penetrate into the root dentinal tubules under different circumstances. The effect of dentine surface treatment on the penetration depth, from the pulpal side, in root dentine by determining the number of surviving bacteria per milligram of dentin (CFU/mg) was studied.

Very little information is available about the depth of penetration and number of viable microorganisms in root dentine of teeth that are still amenable to root canal treatment. Therefore the presence, depth of penetration, morphotypes and the number of colony forming units (CFU) of bacteria in root dentin of restorable teeth with periapical lesions was evaluated in chapter 4.

The clinical experiments (chapter 5 and 6) were conducted to study the number, identities and the fate of bacteria in root canals before, during and after root canal treatment. The influence of one and two visit root canal treatment on number of microorganisms and periapical healing was evaluated.

The recurrent presence of certain species at all stages of root canal treatment (chapter 5) was evaluated in chapter 7. Positive relations between certain strict anaerobic species were found. In chapter 8 the studies presented in this thesis are summarised, conclusions are listed and some suggestions for further study are made.
Chapter 1

In the process of obtaining a comprehensive understanding of the role of bacteria in the etiology of root canal treatment failures, it is essential to first identify the types of bacteria that are commonly found in the root canal system. These bacteria can originate from the oral cavity or from the periapical area and may be found in different locations within the root canal system. Understanding the distribution and characteristics of these bacteria is crucial for developing effective treatment strategies.

The presence of bacteria in the root canal system can lead to the formation of biofilms, which are aggregates of bacteria attached to surfaces. These biofilms can be difficult to eliminate, making them a significant challenge in the treatment of root canal infections. The importance of addressing these biofilms in the root canal treatment process cannot be overstated, as they can contribute to the recurrence of infections and the failure of root canal treatment.

In this context, the development and evaluation of novel treatment modalities for the removal of bacteria from the root canal system become crucial. The literature on the subject is vast, with numerous studies focusing on various methods for disinfecting the root canal system. However, despite the advancements in root canal treatment techniques, the effective elimination of bacteria remains a significant challenge.

The objectives of this thesis are to (1) review the current literature on the etiology of root canal treatment failures, (2) identify the types of bacteria commonly found in the root canal system, and (3) evaluate the effectiveness of different treatment modalities for the removal of bacteria from the root canal system. The thesis will also aim to develop a model for the study of bacterial persistence in the root canal system, with the ultimate goal of improving the success rates of root canal treatment.

This work is intended to contribute to the ongoing efforts in developing effective treatment strategies for root canal infections, with the hope of reducing the prevalence of treatment failures and improving patient outcomes.

14