Apical periodontitis in a Flemish population: an epidemiological study and assessment of influencing factors.

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Chapter 1
Introduction
1.1. Apical periodontitis and its causes

Apical periodontitis (AP) is an inflammatory periradicular lesion of endodontic origin. Dental pulp infection generally occurs as a sequel to dental caries, trauma and operative procedures whereby bacteria enter the pulpal space. Pulpal infections commonly progress to pulp necrosis with subsequent apical periodontitis (Bergenholtz 1990).

These periapical lesions are caused by irritants diffusing from an inflamed pulp, necrotic pulp or infected root canal filling. The main irritants are bacteria. The link between apical periodontitis and bacteria has been extensively demonstrated in the literature (Kakehashi et al. 1965, Bergenholtz 1974, Sundqvist 1976, Möller et al. 1981). These irritants (bacteria, bacterial toxins, bacterial fragments) egress apically from the root canal into the periradicular tissues and initiate inflammation with subsequent tissue alterations. There is no evidence that apical periodontitis can be caused by necrotic pulp tissue per se, via toxic tissue breakdown products (Möller et al. 1981).

Apical periodontitis most often takes the form of reactive granulomas and cysts, with resorption of bone surrounding the affected roots. These responses involve a complex array of immunological mechanisms, some of which act primarily to protect the pulp and the periapical region, whereas others mediate tissue destruction, particularly bone destruction (Stashenko 1998).

Different types of apical periodontitis have been described: symptomatic (acute) apical periodontitis, asymptomatic (chronic) apical periodontitis and apical abscess. The most common type of lesion is the asymptomatic (chronic) apical periodontitis. This type of chronic lesion is long-standing and one of the only symptoms that is a radiographically visible lesion. The patient usually reports no pain, and percussion and palpation tests reveal no difference with the adjacent teeth. Radiographic findings are thus of high importance for diagnosis. The radiographic changes range from a widening of the apical part of the periodontal ligament to distinct periapical radiolucency.

It is important to realize that the periradicular infection is not self-resolving; the microbial infection is mainly localized inside the root canal and the absence of vital tissue impairs the immune response. Nevertheless, the host’s immune response and
the microbial challenge are more or less in balance and the inflammation is mostly a relatively low-grade, long-standing response. This explains why the majority of apical periodontitis lesions are chronic and progress slowly.

As long as the irritants egress out of the root canal into the periradicular tissues or the host’s defence is unable to remove these irritants from the periapical tissue, destructive and healing processes occur simultaneously in asymptomatic lesions. The pathogenicity and concentration of the micro-organisms, as well as the activity level of the host’s immune response, determine the size and nature (acute or chronic) of the lesion. According to Eriksen (1998), the chance of exacerbation of chronic apical periodontitis is around 5% per year.

1.2. Apical periodontitis and general health

As with other oral infections, debate exists about the role of apical periodontitis in *focal infections*. Focal infection implies dissemination of pathogens from an infected site (focus) to remote parts of the body, where secondary disease arises. With time, the concept of focal infection was expanded to include immune products, causing distant disease or symptoms. The focal infection theory was firstly postulated in the 19th century and the beginning of this century (Miller 1891, Hunter 1900). At that time, a whole series of diseases were associated with oral infections. A series of subsequent publications confirmed this theory (Murray & Saunders 2000). Following these publications, focal infection was debated and recommendations proposed to the dental profession. These recommendations were based on limited scientific research. A limited number of controlled studies and anecdotal reports resulted in the continued promotion of dental extractions and tonsillectomies as a complete cure for systemic diseases (Murray & Saunders 2000). Rhein *et al.* (1926) even justified the extraction of healthy teeth. In the following decades, together with the improvement in dental treatment and endodontic therapy, the focal infection theory was almost totally abandoned by dental practitioners.

In recent years, interest in the issue of focal infection has reoccurred. This is due in part to improved microbiological techniques. Different authors have commented on this topic (Debelian *et al.* 1994, Newman 1996, Li *et al.* 2000, Murray
Evidence exists that transient bacteraemia can cause systemic effects, especially in immunocompromised hosts, due to, for example, chemotherapy, diabetes, corticosteroids, HIV and age (Newman 1996). Data suggest possible involvement of oral pathogens in spreading infections along facial planes, skin diseases, orbital infections, intracranial sequelae, respiratory tract infections, cardiovascular disease, gastrointestinal infections, infection of implants and rheumatoid arthritis (Debelian et al. 1994, Newman 1996, Li et al. 2000).

Of particular interest for the dental profession is that a direct link between dental disease and maxillary sinusitis has been demonstrated (Nenzen & Walander 1967, Frederick & Braude 1974, Falk et al. 1986, Connor et al. 2000).

Although no conclusive data exist on a possible involvement of apical periodontitis as a spontaneous focal nodus, today’s dental professionals should be aware of the presence of apical periodontitis and its possible consequences for general health. Apical periodontitis should therefore be treated as every other infectious disease, that is, by the removal of the cause of infection.

1.3. Endodontic epidemiology and apical periodontitis

Apical periodontitis is an acute or chronic inflammatory lesion around the apex of a tooth caused by bacterial infection of the root canal system. The aim of endodontic treatment is either to prevent the development of apical periodontitis or to establish conditions favouring healing. Infection control and elimination of bacteria from the root canal are therefore the keystones of endodontic treatment. There are in this respect thus essential questions related to the occurrence of apical periodontitis and its treatment (Eriksen 1998):

1. Is it possible, with present knowledge and modern principles of endodontic treatment, to control and eliminate apical periodontitis?
2. To what extent are we, as a dental profession, succeeding in achieving that goal?

The first question can be answered using information from experimental and clinical research. An appropriate answer to the second can be assessed mainly from epidemiological investigations. According to Eriksen et al. (2002), in a survey of the
three most influential international scientific endodontic journals during the last
decade, over 2000 reports dealt with experimental and clinical studies. But only 25
epidemiological studies could be found. This clearly demonstrates the need for more
epidemiological data. These epidemiological data are needed to study possible
additional influences and less specific factors (Eriksen et al. 2002). Controlled clinical
studies and epidemiological studies can then better complement each other
symbiotically and improve treatment strategies.

Although the number of epidemiological studies is limited, a general
international trend is observed. The prevalence of apical periodontitis on
endodontically treated teeth is several times higher than for all other teeth (Table 1-1).
It is obvious that there is an association between the presence of apical
periodontitis (which may refer to disease prevalence and treatment outcome) and the
endodontic treatment provided (exposure information).

Epidemiology is often considered as belonging to public health policy and
health planners with only limited relevance to dental practitioners and their individual
patients. However, epidemiologic research has much more to offer to the dental
practice (Eriksen 1998). The relevance of the following questions may elucidate this
assertion:

1. Is the manifestation and nature of a disease, as it appears in an individual,
similar to most other cases, or is it unusual?
2. What are the major causes and contributing factors for a specific condition
or disease in society?
3. Are there certain characteristics about the group from which the majority of
cases appear?
4. What is the probability that the disease will respond to a specific treatment?
A proper answer to these questions is primarily provided by data from
epidemiological studies, augmented and completed, with information from
experimental and clinical research (Eriksen 1998).

Studies on adult periapical health have not yet been performed in Belgium. No
data were available on the prevalence of apical periodontitis on root filled teeth, as
well as on non-root filled teeth in a Belgian population. These data can be valuable
for a number of purposes: causal parameters in apical periodontitis, inventory of
endodontic treatment performed in Belgium (in general practice), educational
purposes and planning of dental care strategy by the government.
Table 1-1: Prevalence of apical periodontitis and root-canal fillings

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Country</th>
<th>No. of teeth</th>
<th>% AP</th>
<th>% endo</th>
<th>% endo with AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bergström et al.</td>
<td>1987</td>
<td>Sweden</td>
<td>6593</td>
<td>3.5</td>
<td>6.5</td>
<td>28.8</td>
</tr>
<tr>
<td>Eckerbom et al.</td>
<td>1987</td>
<td>Sweden</td>
<td>4889</td>
<td>5.2</td>
<td>13.0</td>
<td>26.4</td>
</tr>
<tr>
<td>Ödesjö et al.</td>
<td>1990</td>
<td>Sweden</td>
<td>17430</td>
<td>2.9</td>
<td>8.6</td>
<td>24.5</td>
</tr>
<tr>
<td>Eriksen &amp; Bjertness</td>
<td>1991</td>
<td>Norway</td>
<td>2940</td>
<td>3.5</td>
<td>6.0</td>
<td>36.6</td>
</tr>
<tr>
<td>Imfeld</td>
<td>1991</td>
<td>Switzerland</td>
<td>2004</td>
<td>8.4</td>
<td>20.3</td>
<td>31.0</td>
</tr>
<tr>
<td>De Cleen et al.</td>
<td>1993</td>
<td>The Netherlands</td>
<td>4196</td>
<td>6.0</td>
<td>2.3</td>
<td>39.2</td>
</tr>
<tr>
<td>Eriksen et al.</td>
<td>1995</td>
<td>Norway</td>
<td>2981</td>
<td>1.5</td>
<td>3.4</td>
<td>18.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3917</td>
<td>1.4</td>
<td>3.4</td>
<td>25.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3282</td>
<td>0.6</td>
<td>1.3</td>
<td>38.1</td>
</tr>
<tr>
<td>Buckley &amp; Spångberg</td>
<td>1995</td>
<td>USA</td>
<td>5972</td>
<td>4.1</td>
<td>5.5</td>
<td>31.3</td>
</tr>
<tr>
<td>Weiger et al.</td>
<td>1997</td>
<td>Germany</td>
<td>7987</td>
<td>3.0</td>
<td>2.7</td>
<td>61.0</td>
</tr>
<tr>
<td>Saunders et al.</td>
<td>1997</td>
<td>United Kingdom</td>
<td>8420</td>
<td>4.9</td>
<td>5.6</td>
<td>58.1</td>
</tr>
<tr>
<td>Marques et al.</td>
<td>1998</td>
<td>Portugal</td>
<td>4446</td>
<td>2.0</td>
<td>1.5</td>
<td>21.7</td>
</tr>
<tr>
<td>Sidaravicius et al.</td>
<td>1999</td>
<td>Lithuania</td>
<td>3892</td>
<td>7.2</td>
<td>8.2</td>
<td>35.6</td>
</tr>
<tr>
<td>Kirkevang et al.</td>
<td>2001</td>
<td>Denmark</td>
<td>15984</td>
<td>3.4</td>
<td>4.8</td>
<td>52.2</td>
</tr>
<tr>
<td>Boucher et al.</td>
<td>2002</td>
<td>France</td>
<td>5373</td>
<td>7.4</td>
<td>19.1</td>
<td>29.7</td>
</tr>
<tr>
<td>Lupi-Pegurier et al.</td>
<td>2002</td>
<td>France</td>
<td>7561</td>
<td>7.3</td>
<td>18.9</td>
<td>31.5</td>
</tr>
<tr>
<td>Dugas et al.</td>
<td>2003</td>
<td>Canada</td>
<td>16148</td>
<td>3.2</td>
<td>2.5</td>
<td>45.5</td>
</tr>
<tr>
<td>Jiménez-Pinzón et al.</td>
<td>2004</td>
<td>Spain</td>
<td>4453</td>
<td>4.2</td>
<td>2.1</td>
<td>64.5</td>
</tr>
</tbody>
</table>

% AP: percentage apical periodontitis, % endo: percentage endodontically treated teeth, % endo with AP: percentage endodontically treated teeth associated with apical periodontitis

1.4. Present knowledge and modern principles of endodontic treatment

As previously stated, the biological and therapeutic aim of endodontic treatment is either to prevent apical periodontitis or to create optimal conditions for healing, based on removal of infection and elimination of bacteria from the root canal and prevention of reinfection. The basic principles of root canal therapy are CLEANING — SHAPING — FILLING.
1.4.1. Cleaning

Through cleaning, the practitioner aims for elimination of all surviving microorganisms from the root canal and for the creation of a sterile root canal. Studies have shown that rendering an already infected root canal sterile is virtually impossible (Byström & Sundqvist 1981, Sjögren et al. 1997, Siqueira et al. 2002). It appears that a minimum number of bacteria are needed to induce pathology (Korzen et al. 1974) and not all species present in endodontic infections are able to cause periapical disease (Sundqvist et al. 1979, Dahlén et al. 1982, Fabricius (2) et al. 1982, Baumgartner et al. 1992, Siqueira et al. 1998).

A sterile working environment is required to remove as many bacteria as possible from root canals and prevent further contamination of the root canal during treatment. The tooth should therefore be isolated from the rest of the oral cavity with a rubber dam to prevent the ingress of saliva and accompanying micro-organisms. There is general agreement that application of a rubber dam for endodontic treatment is mandatory (European Society of Endodontology 1994, American Association of Endodontists 1998). Following the application of a rubber dam, the endodontic procedures attempt to remove infection from a root canal with root canal disinfectants and debridement techniques. These debridement techniques are also important to shape the root canal to allow adequate apical cleaning and appropriate filling of the root canal.

The different aspects of root canal cleaning have been studied and various root canal irrigants such as sodium hypochlorite, quaternary ammonium compounds, sterile saline, iodine potassium iodide, hydrogen peroxide and chlorhexidine (Ingle et al. 2002) have been discussed in the endodontic literature. Current evidence suggests the use of sodium hypochlorite (0.5 to 5.25%) during root canal debridement, in combination with 15 to 20% EDTA (ethylenediaminetetraacetic acid, liquid or paste) to further improve the microbial and tissue solving effect (Baumgartner et al. 2002) along with to the removal of the smear layer.

1.4.2. Cleaning and shaping

Various techniques and instruments have been proposed for root canal cleaning and shaping. The endodontic hand file in various forms is an excellent tool
for root canal debridement, but working with it is difficult and time consuming. Stainless steel as well as nickel titanium hand files are now being used. Tepel et al. (1995) studied the instrumentation of curved canals by different types of hand files. They found that flexible stainless steel instruments with modified tips (less sharp edges) were a substantial improvement compared with conventional stainless steel reamers and K-files and, somewhat surprisingly, that they performed better in curved canals than the flexible titanium-based instruments tested. Flexible stainless steel instruments also needed less time for preparation due to an increased dentin removal capacity. Hedström files have been shown to remove more dentin than other type of files on the inner side of the curvature of a root, increasing the risk for lateral root perforations (stripping) (Al-Omari et al. 1992). One short-term clinical study (one year) found that teeth treated with nickel-titanium files demonstrated a significantly higher decrease in AP than stainless-steel K-files (Pettiette et al. 2001). The use of flexible instruments, be it flexible stainless steel or nickel-titanium files, is therefore recommended. Although nickel-titanium hand files possess an increased flexibility (Walia et al. 1988), their use has never been very widespread. With the introduction of rotary nickel-titanium endodontic files, the use of nickel-titanium became more popular. These instruments allow faster preparation of root canals compared with hand instruments (Gluskin et al. 2001, Schäfer et al. 2003). The selection of instrumentation and techniques plays an important role in clinical success, based on their efficacy in removal of bacteria. No difference was found in this regard between hand and rotary instruments (Siqueira et al. 2002).

A keystone of efficient instrumentation is the combination of root canal irrigants and instrumentation technique. Coldero et al. (2002) found that coronal flaring (widening) of the root canal was beneficial for the irrigant in reaching apically. Extrusion of dentin debris into the periapical area during root canal preparation has been associated with persistent inflammation (Seltzer et al. 1968, Torneck et al. 1973). The crown-down pressureless technique, balanced force technique and engine driven instrumentation showed the least apical extrusion (Ruiz-Hubard et al. 1987, McKendry 1990, Al-Omari & Dummer 1995, Reddy & Hicks 1998, Ferraz et al. 2001). A crown-down approach during root canal instrumentation is therefore recommended.

The success rate is reduced in cases of persistent bacterial infection in the root canal at the time of the root filling or reinfection of the root canal filling (Byström
et al. 1987, Sjögren et al. 1997). This finding is indicative for the constant risk of induction of periapical inflammation. Inter-appointment root canal dressings can be used as an additional disinfectant following root canal preparation. Studies have shown that regrowth of bacteria can occur in an empty root canal (Byström & Sundqvist 1981, Siqueira et al. 2002). These dressings can prevent this. Calcium hydroxide is recommended as the standard intracanal dressing in root-canal treatment (Byström et al. 1985, Sjögren et al. 1991) for its antibacterial effect. Mechanical instrumentation alone causes a 100- to 1000-fold reduction in the number of bacteria (Byström & Sundqvist 1981), but complete elimination in only 20 to 43% of cases. Additional antibacterial irrigation with 0.5% NaOCl provides complete disinfection in 40 to 60% of the teeth treated (Byström & Sundqvist 1983). The subsequent application of a calcium hydroxide dressing brings the percentage of bacteria-negative teeth to 90-100% (Byström et al. 1985). Nevertheless, there is some evidence that a single placement of calcium hydroxide may be insufficient for a predictable elimination of the root canal infection (Matsumiya & Kitamura 1960, Sundqvist et al. 1998). Calcium hydroxide also dissolves necrotic tissue and enhances the tissue dissolving effect of NaOCl (Hasselgren et al. 1988).

The recommended number of treatment sessions in case of infected root canals is still a matter of debate. Working in two or more sessions has been recommended to allow placement of a root canal dressing. Peters et al. (1995) have recommended — for practical reasons — that endodontic treatment should be completed in a single visit without any intracanal dressing arguing that bacteria surviving in the root canal system after root canal preparation are entombed by obturating the root canal and perish as a result of lack of substrate. Moreover, some authors pointed out that the antibacterial activity of root canal sealers and gutta-percha (in vitro) could contribute to the elimination of intracanal organisms (Moorer & Genet 1982, Weiger et al. 1993). The number of treatment sessions does not seem to have an effect on treatment outcome (Trope et al. 1999, Weiger et al. 2000), as long as no more than two treatment sessions are performed (Cheung 2000, Sirén et al. 1997). When multiple visits are required for root canal treatment, with each visit the chance increases of infection of the root canal with treatment resistant bacteria like Enterococcus faecalis (Sirén et al. 1997). A prerequisite for multi-visit treatment is therefore the placement of a root canal dressing. Otherwise, the success percentage is negatively influenced (Trope et al. 1999).
Historically, caustic products containing organic components such as paraformaldehyde, chlorophenol, parachloromonophenol, creosote, arsenic anhydride, and iodoform have been used. It has been argued that most of these products should be prohibited since they are highly toxic, allergenic, mutagenic and carcinogenic and are harmful to patients (Lewis 1998). Another reason to avoid the use of such products is their short term and limited effectiveness.

1.4.3. Root canal filling

Obturation of the root canal is an essential part of endodontic treatment. It therefore must be performed according to the highest clinical standards. The function of the root filling is to act as a barrier to infection of periapical tissues. According to Sundqvist & Figdor (1998), root fillings fulfil this role in three ways:

1. Blockade of any communication between the oral cavity and the periradicular tissues (coronal leakage)
2. Entombment of any bacteria surviving in the root canal system
3. Stopping tissue fluid derived from periapical tissues from reaching bacterial cells in the root canal system and maintaining their survival (nutritional source, apical leakage)

Root canal treatment performed to high technical standards remains a prerequisite for long-term success (Strindberg 1956, Bergenholtz et al. 1979, Eckerbom et al. 1987, Ödesjö et al. 1990, Sjögren et al. 1990). Agreement exists in the literature that the length of the root filling is an important factor in endodontic treatment success (Sjögren et al. 1990, Wu et al. 2000, Dammaschke et al. 2003, Ørstavik et al. 2004). Sjögren et al. (1990) found that root fillings ending more than 2mm short of the radiographic apex showed an impaired healing rate. There is still some disagreement, however, about the effect of the homogeneity of the root filling on the periapical status. While Ödesjö et al. (1990), Sjögren et al. (1990) and Eriksen et al. (1995) found no difference between compact and poorly compacted root fillings in relation to periapical lesions, Bergström et al. (1987), Petersson et al. (1991) and Kirkevåg et al. (2000) did.

Studies have also shown that apical overfilling into the periapical tissues reduces the success rate of the treatment (Strindberg 1956, Bergenholtz et al. 1979, Sjögren et al. 1990, Dammaschke et al. 2003, Ørstavik et al. 2004). The filling
material and sealer by themselves are not capable of inducing an expanding bone lesion. Different studies indicated that overfilling a sterile canal did not influence the outcome of treatment (Byström et al. 1987, Sundqvist et al. 1998). It appears that microbiological infection transported into the periapical tissue is the cause of failure rather than the filling material. This finding is indirectly corroborated by the finding of Ørstavik et al. (2004) who concluded that over-instrumentation had a negative effect on the treatment outcome of root canal fillings.

1.4.4. Quality of the root filling and the coronal restoration

The risk of reinfection of the root canal and periapical tissues has been related to the quality of the root filling and the coronal filling (Saunders & Saunders 1994). Ray & Trope (1995) have shown in a radiographic study that the technical quality of both the coronal restoration and the root canal filling influence the prevalence of apical periodontitis. Coronal leakage has gained interest in the scientific literature in the recent years. Several studies investigated the effect of the type of coronal restoration on the success or survival of teeth following root canal treatment. Aquilino & Caplan (2002) found that when tooth type and caries at access were controlled, endodontically treated teeth not crowned after obturation were lost at a 6.0 times greater rate than teeth crowned after obturation. In contrast, Sjögren et al. (1990) found that teeth restored with crowns had a worse prognosis. Cheung & Chan (2003) concluded that teeth restored with crowns survived significantly longer than those with intracoronal plastic restorations only. Dammaschke et al. (2003) found similar results, but in their study, the type of plastic restoration (amalgam or composite) had no significant influence on treatment outcome. Barthel et al. (2004) found, in a study on human cadavers, that there was no correlation between the type of coronal restoration on root filled teeth and the histological status of the periapex. The placement of a base under a coronal filling in root filled teeth has not yet been investigated for its possible effect on treatment outcome.

Contradictory data exist on the effect of root canal posts on the prevalence of apical periodontitis. Kvist et al. (1989) and Tronstad et al. (2000) found that the prevalence of apical periodontitis was not influenced by the presence of a root canal post. Eckerbom et al. (1991) found an increase in apical periodontitis in the presence of a root canal post, but their study only included crowned teeth. Aquilino & Caplan
(2002) found that crowned teeth with posts had a better long-term survival. Cheung & Chan (2003) found that the type of post influenced the survival of teeth: all-amalgam post-cores or prefabricated posts were associated with a significantly longer survival than no posts or cast posts. There is no obvious explanation for these contradictory data. Based on the literature, it appears that microleakage can be minimized when post preparation is performed with a heated instrument as soon as possible after canal obturation and when an absolute minimum of 3mm root filling is conserved at the apical portion of the root canal (De Cleen 1993, Heling et al. 2002). After post space preparation, the clinician’s main concern is the small volume of obturating material that remains in the root canal. Cementing the post a soon as possible after canal obturation may help minimize microleakage (Fox & Gutteridge 1997).

1.4.5. Effect of pre-operative factors on treatment outcome

Along with the above mentioned intra-operative and post-operative factors that influence the treatment outcome in endodontics, pre-operative factors have been investigated for their possible effect on treatment outcome.

Age and gender of the patients do not appear to significantly influence the prevalence of apical periodontitis after root canal therapy (Kerekes & Tronstad 1979, Sjögren et al. 1990, Ørstavik 1996, Benenati & Khajotia 2002). Others also found that gender was of no importance for treatment outcome (Chugal et al. 2001, Dammaschke et al. 2003). In a recent multivariate study on treatment outcome, Ørstavik et al. (2004) found that the gender of the patients had no effect, whereas the age had a significant effect.

The effect of tooth type on endodontic treatment outcome was also investigated. Some studies found no difference in treatment outcome between the different types of teeth (Ørstavik 1996, Weiger et al. 2000, Ørstavik et al. 2004), while others did: Kerekes & Tronstad (1979) found no difference in prognosis between anterior and posterior teeth, but canines and maxillary second premolars scored significantly better than other teeth. Benenati & Khajotia (2002) reported that maxillary anterior teeth scored the best, while mandibular molars had the lowest success percentage. Field et al. (2004) found anterior teeth to be more successful after endodontic treatment than posterior teeth. Aquilino & Caplan (2002) found that endodontically treated second molars were lost at a greater rate than other teeth.
Cheung & Chan (2003) found that maxillary and mandibular molars and maxillary premolars had a significantly lower survival probability following root canal therapy than maxillary and mandibular anteriors and mandibular premolars. Although there is no consensus on the effect of the tooth-type, it seems logical that posterior teeth, due to their higher number of canals, have a theoretical chance of failure that is the summation of the possible chance of failure for each canal individually. Moreover, anatomical variations can also influence the treatment outcome.

Although the presence of pre-operative symptoms can be an indication of the presence of specific types of bacteria in the root canal (Dáhlen & Haapasalo 1998), the prognosis is not different between asymptomatic and symptomatic (pre-operative) teeth (Byström et al. 1987, Sjögren et al. 1990, Weiger et al. 2000, Ørstavik et al. 2004).

The prognosis of endodontic treatment of teeth with small lesions (<5mm) seems to be better than teeth with larger lesions (Strindberg 1956, Weiger et al. 2000, Cheung & Chan 2003, Chugal et al. 2001, Ørstavik et al. 2004), although other authors found no difference in treatment outcome (Byström et al. 1987, Sjögren et al. 1990, Sjögren et al. 1997).

The effect of the periodontal condition of the teeth on the endodontic treatment outcome in case of apical periodontitis has not yet been investigated thoroughly. One study found no influence of this factor on the prognosis (Sjögren et al. 1990). Ørstavik et al. (2004) found the height of marginal bone support to be a significant factor for the prognosis of the root canal treatment (worse prognosis with loss of height).

The pre-operative pulpal status (vital vs. necrotic teeth) has shown to be a significant prognostic factor for endodontic success (Ørstavik et al. 2004, Chugal et al. 2001, Kojima et al. 2004). A study of Smith et al. (1993) found root canal treatment on vital teeth to be more successful than non-vital teeth (p<0.03), although necrotic teeth without a periapical radiolucency had success rates (87.01%) which were not statistically significantly different from those of vital teeth (88.89%). This indicated that it is not the vitality of the pulp, but the presence of bacterial infection that influences prognosis of endodontic treatment.

The possible effect of the systemic health of patients on the outcome of conventional endodontic treatment of apical periodontitis has not yet been investigated thoroughly. One study found that in case of a pre-operative periapical lesion, the root canal treatment outcome was compromised in patients with diabetes.
mellitus (Fouad & Burleson 2003). More research however is needed to support this finding.

A possible explanation for the different conclusions in the different studies could be due to differences in follow-up intervals, total follow-up time, selection of the studied samples and sample sizes.

A study by Kirkevang and Wenzel (2003) investigated the risk indicators for apical periodontitis. They investigated socio-economic variables as well as dental variables. The latter authors found a significant increase in the presence of apical periodontitis in conjunction with some socio-economic variables: older patients, smoking, occupation, having children in the past two years, high use or no use of dental services. The following dental variables had a significant and increasing effect on the presence of apical periodontitis: the number of inadequate coronal fillings per patient, the number of root fillings per patient and a decreased number of teeth. Another study found no significant influence of smoking on the prevalence of either apical periodontitis or endodontic treatment (Bergström & Eliasson 2004).

Less is known on the effect of occlusal parameters on the treatment outcome in endodontics. Iqbal et al. (2003) found in a study on endodontically treated and crowned teeth that the presence of functional contacts (sole or group) between opposing teeth during oral functioning had the strongest effect on treatment outcome in a logistic regression model. A possible explanation for this finding can be an effect of the occlusion on inflammation and healing of tissue or the effect of occlusion on the stability of the cement, whereby fracture and dissolution of the cement could cause an increased leakage. ElDeeb and Andreasen (1991) reported that hyper- and hypo-occlusion had no effect on healing of the periodontium in rats. Kumazawa et al. (1995) found a positive correlation between traumatic occlusion and periapical pathoses in rats. They suggested that occlusal trauma might be associated with a delay in the spread of inflammation to the periapical area.
1.5. Coronal leakage

Historically, apical leakage of the root filling has been considered as a major problem. It was thought that substances leaked from the periapical tissues into the unfilled or poorly filled root canal and that these host substances stagnated in the root canal and subsequently broke down and then leaked back into the periapical tissues and induced inflammation (Ingle & Glick 1965). This theory proved to be wrong, since it has been demonstrated that sterile necrotic tissue does not induce inflammation (Möller et al. 1981) and that apical periodontitis can heal after adequate cleaning of the root canal, even without root filling (Klevant & Eggink 1983, Donnelly 1990).

The first authors to point out the effect of coronal leakage were Marshall and Massler (1961) and this topic was discussed again by Swanson & Madison in 1987. Apical leakage is still considered as a factor in the failure of endodontic treatment, but in recent years, more attention has been paid to coronal leakage (Saunders & Saunders 1994). Several authors have reported that even with satisfactory root fillings, leakage of bacteria and bacterial products along the length of the root canal is inevitable (Swanson & Madison 1987, Torabinejad et al. 1990, Khayat et al. 1993, Trope et al. 1995). It therefore seems to be of great importance that the coronal access cavity is properly sealed to decrease the risk of new contamination.

Recent radiographic studies have investigated the importance of coronal leakage further. Ray & Trope (1995) and Kirkevang et al. (2000) found that the technical quality of coronal restorations, scored only on radiographs, had a significantly greater impact on periapical health than the technical quality of the root filling. However, Tronstad et al. (2000) found that the technical quality of the coronal restoration was significantly less important than the technical quality of the root filling. A very recent study on human cadavers found a statistically significant impact of the radiographically determined quality of the coronal seal on the histological state of a root-filled tooth (Barthel et al. 2004). None of the three above mentioned studies investigated the clinical quality of the coronal restoration.
1.6. Treatment outcome: theoretical conditions versus routine clinical reality

Treatment outcome, and as a result, apical periodontitis, is influenced by less specific, more distant causes such as dentists’ skills and the attitudes, behaviour and priorities of patients in their social environment. These factors form causal patterns by interacting in complex ways. They may even be more important causes of disease than more directly related pathogens (Eriksen et al. 2002). Epidemiological studies are the only scientific approach to enlighten such interactions and thereby broaden our concept of health and disease. Results from epidemiological studies relate more to real life conditions (higher external validity) than experiments and controlled clinical trials.

The outcome of endodontic treatment performed in controlled clinical studies and epidemiological studies do not coincide. Representative data are shown in Table 1-2 (adapted from Eriksen 1998). There is a marked difference between the success rates in controlled clinical follow-up studies and in cross-sectional epidemiological studies. This discrepancy in success rates may reflect a difference in the quality of endodontic treatment performed, despite improvements to instruments and materials, as well as advances in the understanding of the disease process. Furthermore, in controlled clinical trials, endodontic specialists or students under supervision mostly provide treatment. This is far from the clinical reality of daily general practice. The difference between these figures should be investigated further for causal factors. The analysis of these factors can be used subsequently to postulate solutions for daily practice. Two frequently postulated factors in endodontic literature are the quality of the root filling and the coronal seal (Saunders & Saunders 1994, Ray & Trope 1995, Friedman 1998, Tronstad et al. 2000).

It would be interesting to analyse how dentists perform endodontic treatment. Possible explanations for the increased failure rates may be found in the way endodontics is performed in daily practice. Although clear guidelines have been defined by the two major endodontic societies for root canal treatment (European Society of Endodontology 1994, American Association of Endodontists 1998), questions remain as to what level these guidelines are followed in daily practice. Data from epidemiological studies suggest that the quality of endodontic treatment
performed in daily practice across Europe and North America is poor (Kirkevang & Hørsted-Bindslev 2002).

Table 1-2: Results of endodontic treatment based on the presence of apical periodontitis evaluated from radiographs: comparison between clinical and epidemiological studies (adapted from Eriksen 1998)

<table>
<thead>
<tr>
<th>Clinical studies</th>
<th>Success %</th>
<th>Epidemiological studies</th>
<th>Success %</th>
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</thead>
<tbody>
<tr>
<td>Strindberg 1956</td>
<td>87</td>
<td>Bergenholtz et al. 1973</td>
<td>69</td>
</tr>
<tr>
<td>Grahnén &amp; Hansson 1961</td>
<td>83</td>
<td>Kerekes &amp; Bervell 1976</td>
<td>75</td>
</tr>
<tr>
<td>Grossman et al. 1964</td>
<td>90</td>
<td>Axelsson et al. 1977</td>
<td>75</td>
</tr>
<tr>
<td>Engström &amp; Lundberg 1965</td>
<td>77</td>
<td>Laurell et al. 1983</td>
<td>75</td>
</tr>
<tr>
<td>Harty et al. 1970</td>
<td>90</td>
<td>Hugoson et al. 1986</td>
<td>70</td>
</tr>
<tr>
<td>Molven 1974</td>
<td>87</td>
<td>Allard &amp; Palmquist 1986</td>
<td>73</td>
</tr>
<tr>
<td>Kerekes &amp; Tronstad 1979</td>
<td>91</td>
<td>Bergström et al. 1987</td>
<td>71</td>
</tr>
<tr>
<td>Barbakow et al. 1980</td>
<td>87</td>
<td>Eckerbom et al. 1987</td>
<td>74</td>
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<tr>
<td>Nelson 1982</td>
<td>86</td>
<td>Ödesjö et al. 1990</td>
<td>76</td>
</tr>
<tr>
<td>Morse et al. 1983</td>
<td>95</td>
<td>Eriksen &amp; Bjertness 1991</td>
<td>63</td>
</tr>
<tr>
<td>Ingle &amp; Backland 1985</td>
<td>94</td>
<td>Imfeld 1991</td>
<td>69</td>
</tr>
<tr>
<td>Ørstavik et al. 1987</td>
<td>93</td>
<td>De Cleen et al. 1993</td>
<td>61</td>
</tr>
<tr>
<td>Sjögren et al. 1990</td>
<td>91</td>
<td>Buckley &amp; Spångberg 1995</td>
<td>69</td>
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<tr>
<td>Smith et al. 1993</td>
<td>84</td>
<td>Weiger et al. 1997</td>
<td>39</td>
</tr>
<tr>
<td>Benenati &amp; Khajotia 2002</td>
<td>91</td>
<td>Saunders et al. 1997</td>
<td>42</td>
</tr>
<tr>
<td>Farzaneh et al. 2004</td>
<td>85</td>
<td>Marques et al. 1998</td>
<td>78</td>
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<tr>
<td></td>
<td></td>
<td>Sidaravicius et al. 1999</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kirkevang et al. 2001</td>
<td>48</td>
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<tr>
<td></td>
<td></td>
<td>Boucher et al. 2002</td>
<td>70</td>
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<td>Lupi-Pegurier et al. 2002</td>
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<td>Dugas et al. 2003</td>
<td>55</td>
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<tr>
<td></td>
<td></td>
<td>Jiménez-Pinzón et al. 2004</td>
<td>36</td>
</tr>
</tbody>
</table>

Average success % 89  Average success % 65
It seems that the methods presently used in general dental practice for endodontic treatment are not able to prevent or cure apical periodontitis effectively, as can be seen in Table 1-1. Eriksen et al. (2002) mentioned that nothing is known about the attitude and skills of dentists regarding endodontic treatment in relation to epidemiological research on apical periodontitis.

1.7. Studies on endodontic flora

Dental pulp infections occur as a sequel to dental caries, trauma and dental operative procedures. Infection of the coronal pulp may spread apically, usually causing necrosis of the pulpal tissues, and may reach the apical part of the root canal. The infection then invades the periapical area, resulting in local bone destruction (Kirkevang & Hørsted-Bindslev 2002). The causal relationship between bacteria infecting the root canal system and apical periodontitis is well-established (Kakehashi et al. 1965, Sundqvist 1976, Möller et al. 1981). Many reasons contribute to endodontic failures, such as poor technical quality of root fillings, instrument fractures, root perforations. However, these factors will only contribute to endodontic failures if they are accompanied by microbial infection. The presence of these microbes is required for the preservation and expansion of periradicular disease. There is no evidence that necrotic pulp tissue per se can elicit periapical inflammation (Stashenko 1998). Thus, infection of the pulpal space seems to be an absolute prerequisite for the genesis of apical periodontitis.

The root canal system is a unique ecological niche for bacteria. The lack of oxygen and the availability of host tissues and primary nutrient sources are important factors in bacterial selection (Sundqvist 1992). The organisms associated with chronically infected root canals are mainly anaerobic and Gram-negative bacteria. Bacterial interactions also influence the composition of the root canal flora. The number of different species detected in a root canal is relatively small, normally between two and eight. More than 20 species have never been found in one root canal (Dáhlen & Haapasalo 1998).

Studies have shown that the number of bacteria that are pathogenic and associated with acute symptoms is considerably lower than the number of bacteria
that are only pathogenic (Dahlén & Haapasalo 1998). Since control of the bacterial infection inside the root canal is important for endodontic success, bacteria resistant to current root canal therapy can compromise the healing of apical periodontitis, or even cause apical periodontitis following therapy.

A limited number of studies are available on the role of bacteria specific in endodontic failures. Enterococci and especially *Enterococcus faecalis* have been studied in refractory apical periodontitis. Enterococci are found in approximately one third of the filled root canals with apical periodontitis (Fraser 1974, Molander *et al.* 1998, Möller 1966). *E. faecalis* appears to be extremely resistant to the antibacterial agents used during root canal treatment. It is one of the few micro-organisms that can survive the anti-bacterial effects of dressing with calcium hydroxide (Byström *et al.* 1985). Enterococci have also shown to have a high ability to survive in root canals as single organisms without the support of other bacteria (Fabricius *et al.* 1982).

Coronal leakage of bacteria has been associated with the presence of apical periodontitis (Saunders & Saunders 1994, Ray & Trope 1995). However, no study has yet investigated the effect of leaking coronal restorations on the composition of the root canal flora in both necrotic root canals and in already roots filled teeth.

### 1.8. Techniques for bacterial analysis

An extensive variety and volume of bacteria are present in the oral cavity and potentially leak into root canals exposed to the oral environment. The analysis of these complex bacterial communities has classically been restricted to conventional culture methods. These methods are time-consuming and laborious. Furthermore, only a limited number of the oral microflora can be cultured. Mombelli *et al.* (1989) have shown that the serial dilution anaerobic culture procedure recovers only 20 to 70% of the microscopic count.

Culture-independent molecular techniques have been developed with the aim of studying previously uncultivable and more fastidious species of bacteria. Specifically, DNA-based detection may be helpful in the identification of bacteria. Two molecular techniques are suitable for DNA-based detection:
1.8.1. DNA-hybridization techniques

In DNA-hybridization techniques, small labelled (for visualization) synthetic oligonucleotides (probes) are manufactured and are complementary with a target region in the genome of the target organism. An example of the use of probes is the FISH technique (Fluorescent In Situ Hybridization) (Langendijk et al. 1995, Franks et al. 1998). The hybridization technique is also used as ‘checkerboard’ DNA-DNA hybridization, where large numbers of DNA probes are mounted on a single support membrane. The latter technique permits the simultaneous determination of the presence of a multitude of bacterial species.

Techniques using probes require initial samples of more than $10^4$ bacterial cells to ensure proper detection (Siqueira et al. 2000). Since sensitivity depends strongly on the amount of starting material, amplification techniques have been developed.

1.8.2. DNA-amplification techniques

These techniques amplify exponentially the target nucleic acids to a level suitable for detection by simple agarose gel electrophoresis and ethidiumbromide staining. In combination with probe technology, these methods may further enhance the sensitivity and specificity. The most widely used technique for this purpose is PCR (Polymerase Chain Reaction) (Mullis & Faloona 1987). PCR allows exponential amplification of DNA regions in between the two primer annealing sites. The result is a high number of duplicates of the target DNA.

Two types of primers can be used for amplification purposes: species-specific primers and universal or broad range primers. The former only allow detection of the target species, with high specificity and sensitivity as an advantage. A limitation of species-specific amplification is that the target species selected are based on culture studies and do not account for any uncultivable bacteria or uncultivable biotypes of known species. Both the techniques of species-specific amplification as the hybridization techniques do not allow determining the true diversity of potential pathogens from infected root canals (Rolph et al. 2001).

Techniques utilizing universal or broad-range amplifications have been developed for use in the field of microbial ecology to evaluate members of diverse
microbial communities including uncultivable micro-organisms (Hugenholtz et al. 1998). These techniques use primers that are complementary with conserved regions of a gene that is present in all or most bacteria or fungi. A frequently used gene for this purpose is the 16S rRNA gene. Discrimination between the different organisms can be carried out using post-amplification species-specific hybridizations or non species-specific methods. The non-species specific analysis of the amplification products include:

1. Total length polymorphism. If the sizes of the amplification products are somewhat specific, determination of the fragment lengths can be used for identification (Welsh & McClelland 1991, Jensen et al. 1993).

2. Total sequence polymorphism analysis. Determination of the sequence of the amplicon allows a maximum of information, but is expensive and labour intensive.

3. Partial sequence polymorphism analysis. Instead of determination of the sequence in detail, the sequence polymorphism can be revealed by indirect methods. These can be by using the sequence specific restriction digestion or by using sequence dependent electrophoresis.

3.1. Restriction digestion based differentiation: ARDRA and T-RFLP. T-RFLP (Liu et al. 1997) is a derivative of ARDRA (Vaneechoutte et al. 1992) whereby only the terminal restriction fragment length is determined.

3.2. Sequence dependent electrophoresis techniques: in these techniques the migration speed of the DNA-fragments not only depends on the size of the DNA-fragments but also on their sequence. The latter is achieved by installing denaturation gradients over the gel or during the electrophoresis process.

   a. Single-stranded conformational polymorphism (SSCP) (Moore et al. 2001)
   b. Denaturating gradient gel electrophoresis (DGGE) (Heuer & Smalla 1997)
   c. Temperature gradient gel electrophoresis (TGGE) (Heuer & Smalla 1997)
   d. Temporal temperature gradient gel electrophoresis (TTGE) (Vasquez et al. 2001)
For the purposes of this thesis, the terminal restriction fragment length polymorphism analysis (T-RFLP) (Liu et al. 1997) was selected to describe the microflora in necrotic root canals, as well as in failed root fillings. To date, only one study has used T-RFLP for the characterization of the oral microflora in the saliva of healthy subjects and of patients with periodontitis (Sakamoto et al. 2003). Techniques like T-RFLP may have the additional advantage of high throughput and reproducibility for monitoring bacterial communities (Osborn et al. 2000, Blackwood et al. 2003), thus providing a rapid method of finding major differences between communities and testing hypotheses based on a comparison of samples (Blackwood et al. 2003).
Chapter 2

Aims of the study
The following aims were put forward for this thesis:

1. Studies on adult periapical health have not yet been performed in Belgium. There is no information available on the frequency or success rates of endodontic treatment and the frequency of apical periodontitis, on root filled teeth as well as on non-root filled teeth. These data can be valuable for a number of purposes: causal parameters in apical periodontitis, inventory of endodontic treatment performed in (general practice) Belgium, educational purposes, planning of dental care strategy by the government. Moreover, this specific information for Belgium is important since the different epidemiological studies across Europe and North America (Introduction, Table 1-1) have rendered figures with a considerable spread. The first aim was therefore to evaluate the prevalence and quality of root canal treatment and to determine, using radiographic means, the prevalence of periapical radiolucencies in a Belgian subpopulation.

2. Recent radiographic studies have investigated the importance of coronal leakage. Ray & Trope (1995) and Kirkevang et al. (2000) found that the technical quality of coronal restorations scored only on radiographs had a significantly greater impact on periapical health than the technical quality of the root filling. Tronstad et al. (2000) found that the technical quality of the coronal restoration was significantly less important than the technical quality of the root filling. It remains unclear whether coronal leakage should be assessed clinically, considering that radiographic evaluation may be ineffective due to limitations of radiography. No study has yet investigated the impact of the technical quality of coronal fillings radiographically and clinically (intra-oral inspection), and the technical quality of root canal treatment on periapical health. The second aim was therefore to evaluate root filled teeth on the quality of both root fillings and coronal restorations in a Belgian subpopulation, using radiographic and clinical criteria, as related to the prevalence of periapical radiolucencies.

3. As discussed in the introduction, a difference is noted between the success percentages of endodontic treatment in epidemiological studies and controlled follow-up studies. Data from epidemiological studies suggest that the quality of
endodontic treatment performed in daily practice across Europe and North America is poor (Kirkevang & Hørsted-Bindslev 2002). Possible explanations for the increased failure rates could be found in the way endodontics is performed in daily practice.

It seems that the methods presently used in general dental practice for endodontic treatment are not able to prevent or cure apical periodontitis effectively, as can be seen in Table 1-1 (Introduction). Eriksen et al. (2002) mentioned that nothing is known about the attitude and skills of dentists regarding endodontic treatment in relation to epidemiological research on apical periodontitis.

The third aim of this thesis was therefore to gather information on the nature of root canal treatment with respect to different aspects of cleaning, shaping and filling of root canals. In addition, it was also aimed to gain insight into endodontic treatment decisions made in relation to periapical pathology and root canal status and to make an inventory of cases considered for referral.

A questionnaire was developed to gather information on these topics. The aim of the questionnaire was not only to collect baseline data, but also to determine the present level of knowledge of endodontics. Furthermore, it was hoped to gain an insight into potential problems regarding endodontic treatment procedures that could explain the present standard of root canal treatment carried out by general dental practitioners.

4. As mentioned in the introduction, coronal leakage has been recognized as a cause of failure in root canal therapy (Saunders & Saunders 1994). A number of in vitro studies have demonstrated the possibility of bacterial leakage along root canal fillings as well as along temporary coronal restorations (Khayat et al. 1993, Deveaux et al. 1999). These findings were supplemented by data from in vivo studies that indirectly described the effect of coronal leakage (Ray & Trope 1995, Tronstad et al. 2000). These studies gave evidence of an increased incidence of apical periodontitis associated with defective root fillings and with leaking coronal restorations.

No study has yet investigated the effect of coronal leakage on a prospect shift in the composition of the root canal microflora in teeth with apical periodontitis.
The fourth aim of the thesis was then to investigate whether it was possible to see the effect of the radiographic and clinical quality of the coronal restorations on the composition of the root canal microflora of both necrotic teeth and teeth with failing root canal fillings associated with apical periodontitis using an advanced microbiological screening technique, i.e. terminal restriction fragment length polymorphism (T-RFLP). The factor 'quality of the root filling' was also considered in this study.
Chapter 3
Periapical health related to the quality of root canal treatment in a Belgian population

This chapter was published as:

ABSTRACT

**Aim:** The aim of this study was to collect data on the prevalence and technical standard of root canal treatment as well as the prevalence of apical periodontitis in Belgium.

**Methodology:** The panoramic radiographs of 206 Belgian adults attending the Dental School of the University Hospital of Gent were examined for endodontic treatment, periapical conditions and coronal restorations.

**Results:** Of the 4617 teeth examined, 6.8% were endodontically treated. Periapical radiolucencies were found in 6.6% of all teeth and in 40.4% of the endodontically treated teeth. More than half of the root filled teeth (56.7%) were scored inadequate on the basis of a criterion evaluating the level of the root canal filling.

**Conclusion:** The endodontic treatment need of this Belgian subpopulation was great and the technical standard of root canal treatment disappointing. The findings indicate that there still is a substantial need for postgraduate endodontic education in Belgium and a need for specialists in Endodontology.
3.1. Introduction

Several follow-up studies have been performed on root canal treatment (Grossman et al. 1964, Sjögren et al. 1990, Eriksen 1991, Friedman 1998) with success rates of more than 90% being common. Most of these studies reported data from endodontic specialists and university clinics. Unfortunately, the success rates in general practice are substantially lower, for example, 65-75% success is commonly reported (Eriksen 1991, Friedman 1998). This discrepancy in success rates may reflect a difference in the quality of endodontic treatment performed, despite improvements to instruments, materials and to advances in the understanding of the disease process.

Epidemiological studies have documented the prevalence of apical periodontitis in various population groups in relation to the quality of endodontic treatment (Table 3-1). However, most of these data come from studies completed in Scandinavia. It is only in recent years that epidemiological information from other countries has become available. These studies highlight the high prevalence of periapical periodontitis, due to the large number of poorly performed root canal treatments (Friedman 1998).

Studies on adult periapical health have not yet been performed in Belgium. Furthermore, there is no information on the frequency or success rates of endodontic treatment and the frequency of apical periodontitis. The aim of the present study was to evaluate the prevalence and quality of root canal treatment and to determine using radiographic means the prevalence of periapical radiolucencies in a Belgian subpopulation.

3.2. Material and methods

3.2.1. Patient selection

The files of patients visiting the Department of Stomatology, Ghent University Hospital, Gent, between 1 January 1997 and 30 November 1997, with a panoramic radiograph, were used. The radiographs used were picked by an independent observer (RDM). The information provided to the examiner was limited to the date of
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Country</th>
<th>No. of teeth</th>
<th>% AP</th>
<th>% endo</th>
<th>% endo with AP</th>
<th>Population</th>
</tr>
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<tr>
<td>Bergström et al.</td>
<td>1987</td>
<td>Sweden</td>
<td>6593</td>
<td>3.5</td>
<td>6.5</td>
<td>28.8</td>
<td>subjects with regular dental care habits</td>
</tr>
<tr>
<td>Eckerbom et al.</td>
<td>1987</td>
<td>Sweden</td>
<td>4889</td>
<td>5.2</td>
<td>13.0</td>
<td>26.4</td>
<td>patients from general practices</td>
</tr>
<tr>
<td>Ödesjö et al.</td>
<td>1990</td>
<td>Sweden</td>
<td>17430</td>
<td>2.9</td>
<td>8.6</td>
<td>24.5</td>
<td>general Swedish population</td>
</tr>
<tr>
<td>Eriksen &amp; Bjertness</td>
<td>1991</td>
<td>Norway</td>
<td>2940</td>
<td>3.5</td>
<td>6.0</td>
<td>36.6</td>
<td>50-year old Oslo citizens</td>
</tr>
<tr>
<td>Imfeld</td>
<td>1991</td>
<td>Switzerland</td>
<td>2004</td>
<td>8.4</td>
<td>20.3</td>
<td>31.0</td>
<td>66-year old Zurich citizens</td>
</tr>
<tr>
<td>Eriksen et al.</td>
<td>1995</td>
<td>Norway</td>
<td>2981</td>
<td>1.5</td>
<td>3.4</td>
<td>18.0</td>
<td>1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3917</td>
<td>1.4</td>
<td>3.4</td>
<td>25.6</td>
<td>1984 35-year old Oslo citizens</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3282</td>
<td>0.6</td>
<td>1.3</td>
<td>38.1</td>
<td>1993</td>
</tr>
<tr>
<td>De Cleen et al.</td>
<td>1993</td>
<td>The Netherlands</td>
<td>4196</td>
<td>6.0</td>
<td>2.3</td>
<td>39.2</td>
<td>dental school patients</td>
</tr>
<tr>
<td>Buckley &amp; Spångberg</td>
<td>1995</td>
<td>USA</td>
<td>5972</td>
<td>4.1</td>
<td>5.5</td>
<td>31.3</td>
<td>dental school patients</td>
</tr>
<tr>
<td>Weiger et al.</td>
<td>1997</td>
<td>Germany</td>
<td>7987</td>
<td>3.0</td>
<td>2.7</td>
<td>61.0</td>
<td>individuals visiting a general dental surgery</td>
</tr>
<tr>
<td>Saunders et al.</td>
<td>1997</td>
<td>United Kingdom</td>
<td>8420</td>
<td>4.9</td>
<td>5.6</td>
<td>58.1</td>
<td>dental hospital patients</td>
</tr>
<tr>
<td>Marques et al.</td>
<td>1998</td>
<td>Portugal</td>
<td>4446</td>
<td>2.0</td>
<td>1.5</td>
<td>21.7</td>
<td>30-39-year old Porto citizens</td>
</tr>
</tbody>
</table>

%AP: percentage apical periodontitis, %endo: percentage endodontically treated teeth, %endo with AP: percentage endodontically treated teeth associated with apical periodontitis
birth and sex of the respective patients, so that the patient’s privacy was respected. Patients younger than 18 and patients having less than 10 remaining teeth were excluded. This resulted in 206 panoramic radiographs to be examined. A distribution of the patient population according to age and sex is shown in Figure 3-1.

All panoramic radiographs used in the present study were taken in the same year (1997) by dental assistants using a Cranex dc2 model sl-4/pt-10 (Soredex, Helsinki, Finland) and Orthodontic X-ray films, medium speed, high contrast (GAC International Inc., New York, USA). The radiographs were processed using a Dürr-Dental AC245L (Dürr-Dental, Bietigheim, Germany) and Dürr-automat developer and fixer (Dürr-Dental, Bietigheim, Germany).

![Figure 3-1: Distribution of the patient sample according to age and sex](image)

3.2.2. Radiographic examination

All radiographs were evaluated under optimal conditions where the surrounding light could be controlled for the best possible radiographic contrast. The radiographs were placed on a viewing box and light surrounding the radiograph was blocked.
Forty panoramic radiographs were assessed to calibrate the two examiners. Inter-examiner agreement (KD vs. GH) with regard to the classification of apical periodontitis was determined by computing Cohen’s kappa (Hunt 1986, Valachovic et al. 1986) for the scores of all teeth (kappa=0.85). On the basis of this score it was felt justified to use the scores of one author (GH) for further evaluation of the radiographic findings. The intra-examiner agreement with a six month interval was high (kappa=0.92). A x5 magnifying-glass was used on most of the radiographs to enhance the image.

The criteria for the radiographic categorization of all teeth, excluding third molars, were as follows (multirooted teeth were classified according to the root exhibiting the most severe periapical condition):

- **Endodontically treated tooth**: tooth with a radio-opaque material in the pulp chamber and/or root canal(s).
- **Apical periodontitis**: widening of the periodontal ligament (widening of the apical part of the periodontal ligament not exceeding two times the width of the lateral periodontal ligament space) or periapical radiolucency (radiolucency in connection with the apical part of the root, exceeding at least two times the width of the lateral part of the periodontal ligament).

In the analysis of the results, both groups were combined as apical periodontitis.

The periapical condition was marked ‘difficult radiographic interpretation’ or ‘indistinct’ when the condition was difficult to score because of superposition on the radiograph.

- **Filling**: restoration of the coronal part of the tooth, which appeared to be a plastic restorative material
- **Crown**: restoration of the coronal part of the tooth, which appeared to be a cast restoration or a porcelain jacket crown

- **Quality of endodontic treatment**:  
  - Root canal filling 0-2mm short of the radiographic apex (adequate)  
  - Root canal filling >2mm short of the radiographic apex (inadequate)  
  - Root canal filling extruded beyond the radiographic apex (inadequate)  
  - Root canal filling limited to the pulp chamber (inadequate)
3.3. Results

A total number of 4617 teeth were examined, i.e. an average number of 22.4 remaining teeth per subject, with a range from 10 to 28.

Table 3-2 gives an overview of the distribution of missing, non-restored, filled, crowned, and endodontically treated teeth according to the tooth type. A differentiation was also made on the presence of caries, which could be detected on the orthopantomographs. Root canal treatment was found in 312 (6.8%) teeth. Teeth in the maxilla were more frequently root-filled (9.4%) as compared to those in the mandible (4.3%); the difference was statistically significant ($p<0.001$, Odds ratio: $1.79<2.31<2.97$). A total of 1222 (26.5%) teeth were restored by means of coronal plastic filling materials and 178 (3.9%) were restored by a crown. Caries was present in 624 (13.9%) teeth.

The periapical conditions of the sample are shown in Table 3-3. Apical periodontitis was detected in 303 (6.6%) teeth irrespective of previous coronal and root canal treatment. It was also found that 130 (63.1%) subjects of the studied group had 1 or more teeth with apical periodontitis (Figure 3-2). The number of teeth with apical periodontitis without endodontic treatment was 177 or 3.8%. Endodontically treated teeth had apical periodontitis in 40.4% of cases.

Statistical analysis of the data in Table 3-4 revealed that for coronally restored teeth the prevalence of apical periodontitis in association with endodontic treatment was statistically significantly higher than without root canal treatment ($p<0.001$). A contradictory finding was that root filled teeth without coronal restorations had a low incidence of apical periodontitis.

The quality of endodontic treatment in relation to the periapical status is shown in Table 3-5. Periapical pathology was present least often in teeth with an adequate root canal filling. Furthermore, teeth with adequate root fillings had statistically significantly less pathology than teeth with root fillings more than 2mm from the radiographic apex ($\chi^2=26.1$ and $p<0.001$, $DF=1$, Odds ratio: $2.39<4.34<7.94$).
Table 3-2: Distribution of missing teeth, non-restored teeth, fillings, crowns and endodontically treated teeth according to the tooth type (n=4617)

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Missing restoration</th>
<th>Filling</th>
<th>Crown</th>
<th>Endodontically treated teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-ca</td>
<td>+ca</td>
<td>-ca</td>
<td>+ca</td>
</tr>
<tr>
<td>11</td>
<td>32</td>
<td>105</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>12</td>
<td>58</td>
<td>87</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>13</td>
<td>21</td>
<td>134</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>14</td>
<td>46</td>
<td>86</td>
<td>13</td>
<td>44</td>
</tr>
<tr>
<td>15</td>
<td>68</td>
<td>57</td>
<td>16</td>
<td>43</td>
</tr>
<tr>
<td>16</td>
<td>66</td>
<td>38</td>
<td>12</td>
<td>69</td>
</tr>
<tr>
<td>17</td>
<td>48</td>
<td>70</td>
<td>16</td>
<td>58</td>
</tr>
<tr>
<td>21</td>
<td>28</td>
<td>109</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>22</td>
<td>29</td>
<td>104</td>
<td>17</td>
<td>31</td>
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<tr>
<td>23</td>
<td>17</td>
<td>136</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>24</td>
<td>48</td>
<td>87</td>
<td>9</td>
<td>43</td>
</tr>
<tr>
<td>25</td>
<td>71</td>
<td>62</td>
<td>11</td>
<td>40</td>
</tr>
<tr>
<td>26</td>
<td>63</td>
<td>36</td>
<td>19</td>
<td>65</td>
</tr>
<tr>
<td>27</td>
<td>48</td>
<td>61</td>
<td>12</td>
<td>72</td>
</tr>
<tr>
<td>31</td>
<td>16</td>
<td>174</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>32</td>
<td>8</td>
<td>179</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>33</td>
<td>3</td>
<td>178</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>34</td>
<td>22</td>
<td>133</td>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>35</td>
<td>49</td>
<td>93</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>36</td>
<td>88</td>
<td>28</td>
<td>14</td>
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<td>15</td>
<td>51</td>
</tr>
<tr>
<td>41</td>
<td>11</td>
<td>186</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>42</td>
<td>11</td>
<td>176</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
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<td>175</td>
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<td>6</td>
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<td>46</td>
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<td>11</td>
<td>64</td>
</tr>
<tr>
<td>47</td>
<td>61</td>
<td>57</td>
<td>13</td>
<td>57</td>
</tr>
</tbody>
</table>

Total 1151 2850 367 968 254 157 21 312

% 61.7 7.9 21.0 5.5 3.4 0.5 6.8

(-ca: free of caries, +ca: with caries)
Table 3-3: Distribution of teeth with periapical pathology seen on OPG according to the tooth type (n=4617)

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Normal periapex</th>
<th>Apical periodontitis</th>
<th>Difficult radiographic interpretation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>11</td>
<td>159</td>
<td>91.4</td>
<td>9</td>
<td>5.2</td>
</tr>
<tr>
<td>12</td>
<td>132</td>
<td>89.2</td>
<td>12</td>
<td>8.1</td>
</tr>
<tr>
<td>13</td>
<td>167</td>
<td>90.3</td>
<td>14</td>
<td>7.6</td>
</tr>
<tr>
<td>14</td>
<td>143</td>
<td>89.4</td>
<td>12</td>
<td>7.5</td>
</tr>
<tr>
<td>15</td>
<td>118</td>
<td>85.5</td>
<td>12</td>
<td>8.7</td>
</tr>
<tr>
<td>16</td>
<td>125</td>
<td>89.3</td>
<td>11</td>
<td>7.9</td>
</tr>
<tr>
<td>17</td>
<td>150</td>
<td>94.9</td>
<td>7</td>
<td>4.4</td>
</tr>
<tr>
<td>21</td>
<td>158</td>
<td>88.8</td>
<td>13</td>
<td>7.3</td>
</tr>
<tr>
<td>22</td>
<td>153</td>
<td>86.4</td>
<td>20</td>
<td>11.3</td>
</tr>
<tr>
<td>23</td>
<td>172</td>
<td>91.0</td>
<td>15</td>
<td>11.1</td>
</tr>
<tr>
<td>24</td>
<td>137</td>
<td>86.7</td>
<td>16</td>
<td>10.1</td>
</tr>
<tr>
<td>25</td>
<td>119</td>
<td>88.1</td>
<td>15</td>
<td>11.1</td>
</tr>
<tr>
<td>26</td>
<td>123</td>
<td>86.0</td>
<td>17</td>
<td>11.9</td>
</tr>
<tr>
<td>27</td>
<td>145</td>
<td>91.8</td>
<td>11</td>
<td>7.0</td>
</tr>
<tr>
<td>31</td>
<td>181</td>
<td>95.3</td>
<td>4</td>
<td>2.1</td>
</tr>
<tr>
<td>32</td>
<td>190</td>
<td>96.0</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
<td>33</td>
<td>197</td>
<td>97.0</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
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<td>178</td>
<td>96.7</td>
<td>5</td>
<td>2.7</td>
</tr>
<tr>
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<td>146</td>
<td>93.0</td>
<td>10</td>
<td>6.4</td>
</tr>
<tr>
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<td>18</td>
<td>15.3</td>
</tr>
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<td>128</td>
<td>90.1</td>
<td>13</td>
<td>9.2</td>
</tr>
<tr>
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<td>97.4</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
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<td>185</td>
<td>94.9</td>
<td>6</td>
<td>3.1</td>
</tr>
<tr>
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<td>196</td>
<td>97.0</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
<td>44</td>
<td>174</td>
<td>96.1</td>
<td>6</td>
<td>3.3</td>
</tr>
<tr>
<td>45</td>
<td>144</td>
<td>92.3</td>
<td>10</td>
<td>6.4</td>
</tr>
<tr>
<td>46</td>
<td>88</td>
<td>80.0</td>
<td>19</td>
<td>17.3</td>
</tr>
<tr>
<td>47</td>
<td>129</td>
<td>89.0</td>
<td>13</td>
<td>9.0</td>
</tr>
<tr>
<td>Total</td>
<td>4226</td>
<td>303</td>
<td>88</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Percentages of endodontic treatment on individual teeth in relation to the periapical condition are not available
Figure 3-2: Distribution of the subjects (n=206) according to the number of teeth showing signs of apical periodontitis

Table 3-4: Periapical status as related to the coronal status

<table>
<thead>
<tr>
<th>Periapical status</th>
<th>Normal</th>
<th>Pathology</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-restored teeth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No root filling</td>
<td>2987 (96%)</td>
<td>135 (4%)</td>
<td>3122</td>
</tr>
<tr>
<td>Root filling</td>
<td>67 (85%)</td>
<td>12 (15%)</td>
<td>79</td>
</tr>
<tr>
<td>Total</td>
<td>3054</td>
<td>147</td>
<td>3201</td>
</tr>
<tr>
<td>Filled teeth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No root filling</td>
<td>976 (96%)</td>
<td>38 (4%)</td>
<td>1014</td>
</tr>
<tr>
<td>Root filling</td>
<td>80 (49%)</td>
<td>84 (51%)</td>
<td>164</td>
</tr>
<tr>
<td>Total</td>
<td>1056</td>
<td>122</td>
<td>1178</td>
</tr>
<tr>
<td>Crowns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No root filling</td>
<td>77 (95%)</td>
<td>4 (5%)</td>
<td>81</td>
</tr>
<tr>
<td>Root filling</td>
<td>39 (57%)</td>
<td>30 (43%)</td>
<td>69</td>
</tr>
<tr>
<td>Total</td>
<td>116</td>
<td>34</td>
<td>150</td>
</tr>
<tr>
<td>Total</td>
<td>4226</td>
<td>303</td>
<td>4529</td>
</tr>
</tbody>
</table>
The sample used in the present study consisted of patients who visited the Department of Stomatology, where most of the patients visiting our dental clinic for the first time are examined. The cohort consisted largely of patients with a general dental treatment need and this was confirmed on the basis of the treatment plans.

Table 3-5: Endodontic treatment quality in relation to the periapical status

<table>
<thead>
<tr>
<th>Length of the root filling</th>
<th>Periapical status</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Normal</td>
<td>Apical periodontitis</td>
<td>Indistinct</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>0-2mm of the radiographic apex</td>
<td>127</td>
<td>40.7</td>
<td>77</td>
<td>60.6</td>
<td>32</td>
</tr>
<tr>
<td>&gt;2mm of the radiographic apex</td>
<td>147</td>
<td>47.1</td>
<td>41</td>
<td>27.9</td>
<td>74</td>
</tr>
<tr>
<td>Extrusion of material through the apex</td>
<td>8</td>
<td>2.6</td>
<td>0</td>
<td>0.0</td>
<td>6</td>
</tr>
<tr>
<td>Material limited to the pulp chamber</td>
<td>22</td>
<td>7.1</td>
<td>1</td>
<td>4.5</td>
<td>14</td>
</tr>
<tr>
<td>Indistinct</td>
<td>8</td>
<td>2.6</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>312</td>
<td></td>
<td>119</td>
<td>38.1</td>
<td>126</td>
</tr>
</tbody>
</table>
outlined in the patient files. There were also patients who suffered from a specific problem that needed specialized treatment by an oral surgeon. Several other studies also screened dental school patients on the same basis (De Cleen et al. 1993, Buckley & Spångberg 1995, Saunders et al. 1997). Extrapolation of the results of the present study to the general population must be done with caution; however, the group reflected a general population sample and there was no skewed recruitment from a socio-economic perspective to be expected, as general dental care at dental schools in Belgium is performed at the fees of the social security, as do the majority of Flemish dentists.

Thirty-five percent of our sample was between 18 and 39 years of age (Figure 3-1); the other age groups were more equally divided. This skewed distribution has been commonly reported by others (Eckerbom et al. 1987, Ödesjö et al. 1990, De Cleen et al. 1993). Younger patients probably seek dental treatment more frequently than older patients, particularly for the diagnosis and evaluation of third molars.

Panoramic radiographs (OPG) were used for screening because of their availability; an intraoral full mouth survey is seldom taken. Ahlqwist et al. (1986) stated that the use of panoramic radiography in epidemiological studies of dental health was acceptable. They found a high specificity and sensitivity of 86 to 96% for the detection of periapical pathology on OPG compared with full mouth surveys. In addition, modern panoramic machines produce better radiographic quality, even in the anterior region. Muhammed & Manson-Hing (1982) found that a periapical survey revealed more radiolucencies than a panoramic survey, although the difference was not statistically significant. The underestimation in scoring periapical lesions on OPG's of good quality is thus low, and the validity of evaluating the periapical conditions on OPG is reliable. This is also confirmed by more recent evaluations of the specificity for detecting periapical lesions on OPG (Molander et al. 1994, Molander et al. 1995).

The quality of endodontic treatment was disappointing, with only 40.7% of root fillings being adequate. In this respect, the data confirm the findings of several other investigators showing poor quality of root canal treatment (De Cleen et al. 1993: 49.4%, Saunders et al. 1997: 38.6%, Buckley & Spånberg 1995: 42%, Ödesjö et al. 1990: 40%, Imfeld 1991: 36%, Bergström et al. 1987: 36.6%, Marques et al. 1998: 46%, Weiger et al. 1997: 41.4%). Although the parameters used to score endodontic quality were not the same for all of these studies, the conclusion must be that the
quality of endodontic treatment was poor. High technical standards during root canal treatment remain the key for success and for a good long term prognosis (Strindberg 1956, Bergenholtz et al. 1979, Eckerbom et al. 1987, Sjögren et al. 1990, Ödesjö et al. 1990). Moreover, it has been proven that the association of endodontic treatment with apical periodontitis decreases when root canal fillings are within 2mm of the radiographic apex (Sjögren et al. 1990). In the present study, only 27.9% of teeth with root fillings more than 2mm from the radiographic apex had a normal periodontal ligament. Those at or within 2mm of the radiographic apex had a normal radiographic ligament space in 60.6% of cases. Root fillings extending beyond the radiographic apex and fillings limited to the pulp chamber gave the poorest results, an outcome reported in several other studies (Bergström et al. 1987, Sjögren et al. 1990, De Cleen et al. 1993, Buckley & Spångberg 1995, Saunders et al. 1997).

The density of the root fillings was not evaluated in the present study as it is difficult to score on an OPG. Endodontic success is founded on three fundamental principles: cleaning, shaping and filling. Only the last parameter can be scored partially on radiographs. In this respect, Ödesjö et al. (1990) and Eriksen et al. (1995) found no statistical difference between compact and poorly compacted root fillings in relation to periapical lesions. However, Bergström et al. (1987) stated that the homogeneity of the root filling was associated with a lower frequency of periapical lesions more so than the length of obturation. Finally, Petersson et al. (1991) found that incompletely obturated root filled teeth developed periapical lesions significantly more often than completely obturated root canals.

Another important factor in endodontic success, and certainly on the long-term, is the inhibition of coronal leakage (Torabinejad et al. 1990, Saunders & Saunders 1994, Ray & Trope 1995, Trope et al. 1995); the technical quality of the coronal restoration may be more important for periapical health than the technical quality of the root filling (Ray & Trope 1995). In addition, it cannot be denied that meticulous cleaning and shaping of the root canal system remains the basic condition for successful root canal treatment. Cleaning and shaping, however cannot be scored on a radiograph.

The incidence of periapical lesions on all teeth was 6.6%. This figure is comparable, or higher than similar studies (Table 3-1). These figures also indicate that the chance of detecting an unexpected periapical lesion in an average patient is very high (the sample consisted of an average of 22.4 remaining teeth per individual.
and thus a chance of 1/15 for detecting a periapical lesion on a tooth). Root filled teeth in our study had periapical pathology present in 40.4% of cases, 10 times higher than on teeth without root fillings (3.8%).

From the periapical lesions seen on a radiograph it is not possible to determine whether or not it is healing. In this respect, Petersson et al. (1991) found that after a 11 year period the number of healed periapical lesions was equal to the number of newly developed lesions, indicating the reliability of cross-sectional studies for scoring the long term success of endodontic treatment. The results are also supported by data reported by Hugoson et al. (1995). Furthermore, it should not be forgotten that periapical lesions are not always detected radiographically. Lesions limited to cancellous bone are almost impossible to detect with conventional radiographic techniques (Le Quire et al. 1977, Bender 1982, van der Stelt 1985), including panoramic radiographs. Bender (1982) determined that 7.1% MBL (mineral bone loss) was a minimum for detecting a lesion on a radiograph in vitro. The MBL in vivo is estimated at 30 to 50% due to the superposition of tissue and fluid. This makes it necessary for a lesion to affect the cortical bone in order for changes to occur radiographically. The prevalence of periapical radiolucencies in this study must thereby be an underestimation of the real situation.

The quality of endodontic treatment is of major influence for root canal treatment. Controlled studies have shown high success rates (Grossman et al. 1964, Sjögren et al. 1990, Eriksen 1991, Friedman 1998). The low success rates in general practice are most likely attributed to the persistence or introduction of microorganisms and their metabolic products in the root canal system and periradicular tissues (Buckley & Spångberg 1995, Nair et al. 1990, Saunders et al. 1997). It has to be reported that only 3% of Belgian dentists used rubber dam outside university clinics, and most of those limited their practice to endodontics and aesthetic dentistry (De Moor 1997). The use of leaking temporary filling materials is another factor of major concern. Prevention of coronal leakage between appointments must be emphasised more and further consideration must be given to sealing access cavities with glass-ionomer cement. Finally, coupled with poor permanent coronal restorations, poorly performed root fillings will enhance the processes of infection and reinfection, which are essential for the preservation or induction of periradicular disease.
3.5. Conclusions

The percentage of apical periodontitis associated with endodontic treatment was disappointing. The findings of the present study demonstrated that a large number of the patients required endodontic treatment. Moreover, a substantial volume of endodontic treatment in the future will be confined to conventional retreatment. Therefore, emphasis on undergraduate endodontic education and continuing education must be a priority in Belgium.
Chapter 4
Periapical health related to the quality of coronal restorations and root fillings

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ABSTRACT

Aim: To evaluate the impact of the quality of coronal restorations scored on a clinical and radiographic basis and the quality of root fillings on periapical health.

Methodology: Periapical radiographs were taken of 745 root filled teeth, at random selected from patients attending the Ghent University Dental School. The teeth had not received restorative treatment in the previous year. The coronal status was scored both clinically according to modified Ryge criteria and radiographically evaluating the presence of signs of marginal leakage or decay. The quality of the root filling was scored according to criteria of length and homogeneity and the periapical status was categorized on the basis of presence or absence of radiographic signs of apical periodontitis. The relationship between coronal status, quality of root filling and periapical health was determined. The data were analysed using $\chi^2$ test, Odds ratio, Spearman’s $r_S$ and logistic regression.

Results: Thirty three percent of the teeth had apical periodontitis as diagnosed radiographically. Teeth with acceptable and unacceptable coronal restorations scored clinically had apical periodontitis in 31.1% and 36.8% respectively; this difference was not statistically significant. The quality of the coronal restorations scored radiographically had a statistically significant influence on the periapical condition ($p<0.001$) with apical periodontitis in 23.8% and 49.1% respectively for acceptable and unacceptable restorations. Marginal decay did not influence the periapical status. Teeth restored without a base under the coronal filling had apical periodontitis in 41.3%, whereas teeth with a base had significantly less ($p<0.005$) apical periodontitis (25.9%). Composite restored teeth exhibited apical periodontitis in 40.5% of cases whilst amalgam restored teeth had apical periodontitis in 28.4% of cases; this difference was statistically significant ($p<0.01$). Root canal posts had no influence on periapical health. The length and homogeneity of the root canal fillings had a significant influence ($p<0.01$ and $p<0.001$ respectively) on the presence of apical periodontitis, as well as the quality of the coronal restoration scored radiographically ($p<0.001$).

Conclusion: The importance of an acceptable coronal restoration, as well as of an acceptable root filling should be emphasized as the technical quality of both influences the periapical status.
4.1. Introduction

The impact of the quality of the root canal filling on the prognosis of root canal treatment has been discussed in several follow-up studies on root canal treatment (Grossman et al. 1964, Sjögren et al. 1990, Eriksen 1991, Friedman 1998). In addition, several authors have described the importance of apical leakage on the treatment outcome of root canal treatment (Strindberg 1956, Schilder 1967, Harty et al. 1970, Adenubi & Rule 1976, Ingle et al. 1985, Cohen & Burns 1998). Already in 1961 Marshall and Massler pointed out the effect of coronal leakage, although it took some time before this was discussed again in the literature (Swanson & Madison 1987).

Apical leakage is still considered as a factor in the failure of endodontic treatment, but in recent years, more attention has been paid to coronal leakage (Saunders & Saunders 1994). Several authors have reported that even with satisfactory root fillings, leakage of bacteria and bacterial products along the length of the root canal is inevitable (Swanson & Madison 1987, Torabinejad et al. 1990, Khayat et al. 1993, Trope et al. 1995). Recent radiographic studies have further investigated the importance of coronal leakage. Ray & Trope (1995) and Kirkevang et al. (2000) found that the technical quality of coronal restorations scored only on radiographs had a significantly greater impact on periapical health than the technical quality of the root filling. Tronstad et al. (2000) found that the technical quality of the coronal restoration was significantly less important than the technical quality of the root filling. It remains unclear whether radiographic evaluation is effective when assessing coronal leakage owing to the limitations of radiographs, or whether clinical inspection of the coronal restoration is also necessary.

No study has yet investigated the impact of the technical quality of coronal fillings radiographically and intra-orally, and the technical quality of root canal treatment on periapical health. The aim of the present study was therefore to evaluate the quality of both root fillings and coronal restorations, using radiographic and clinical criteria, as related to the prevalence of periapical radiolucencies in a Belgian subpopulation.
4.2. Materials and methods

4.2.1. Patient selection and clinical examination

Root filled teeth were selected on panoramic radiographs of randomly selected patients attending the Dental School, Ghent University Hospital, Gent, Belgium, for dental treatment. Only those teeth that were not treated in the preceding year (according to the patient-file or the patient’s recollection) were included in the study. A periapical radiograph was taken of each selected tooth using an Endo Ray film holder (Rinn corp., Elgin, Illinois, USA). This radiographic examination was a part of routine follow-up following endodontic treatment. The coronal status clinically was scored according to a modification (creation of subcategories) of Ryge’s criteria for marginal adaptation (Ryge 1980) (Table 4-1). This assessment was carried out clinically by visual inspection and inspection with a probe. In each case, informed consent was obtained from the patient and the aims of the present study were explained. The radiographs were all taken by two practitioners (GH and CC) and processed on an anonymous basis.

4.2.2. Radiographic examination

All periapical radiographs were evaluated using an X-ray viewer with 5x magnification. The coronal restoration, the presence of a post in the canal, the root canal treatment and the periapical condition were scored according the criteria listed in Table 4-1 (multirooted teeth were classified according to the root exhibiting the most severe periapical condition). The scores for the different parameters were pooled as acceptable and unacceptable as listed in Table 4-1.

Two examiners (GH and CC) were calibrated before the start of the study and at regular intervals during the study. Interobserver (51 teeth were double scored clinically and radiographically) and intraobserver agreement were assessed by computing Cohen’s Kappa (Hunt 1986, Valachovic et al. 1986). All Kappa values were between 0.70 and 0.96. Because of the good interobserver Kappa values, the teeth selected were only scored on each occasion by one of the examiners. The data were then pooled.
Table 4-1: Parameters scored on endodontically treated teeth

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical coronal status</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Good margin (acceptable)</td>
</tr>
<tr>
<td></td>
<td>2. Catching of the explorer, no visible crevice (acceptable)</td>
</tr>
<tr>
<td></td>
<td>3. Crevice limited to the enamel (acceptable)</td>
</tr>
<tr>
<td></td>
<td>4. Crevice penetrating the dentine (unacceptable)</td>
</tr>
<tr>
<td></td>
<td>5. Fracture of restoration (unacceptable)</td>
</tr>
<tr>
<td></td>
<td>6. Detached restoration (unacceptable)</td>
</tr>
<tr>
<td></td>
<td>7. Lost restoration (unacceptable)</td>
</tr>
<tr>
<td></td>
<td>Marginal decay</td>
</tr>
<tr>
<td></td>
<td>Crown or filling</td>
</tr>
<tr>
<td>Radiographic coronal status</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Intact restoration without signs of leakage (acceptable)</td>
</tr>
<tr>
<td></td>
<td>2. Restoration with open margin (unacceptable)</td>
</tr>
<tr>
<td></td>
<td>3. Restoration with recurrent decay (unacceptable)</td>
</tr>
<tr>
<td></td>
<td>Presence or absence of a base under the restoration</td>
</tr>
<tr>
<td></td>
<td>Amalgam or composite</td>
</tr>
<tr>
<td></td>
<td>Presence of a post in the root canal</td>
</tr>
<tr>
<td>Length of the root filling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. root filling terminating 0-2mm from the radiographic apex (acceptable)</td>
</tr>
<tr>
<td></td>
<td>2. root filling terminating &gt;2mm from the radiographic apex (unacceptable)</td>
</tr>
<tr>
<td></td>
<td>3. root filling extending beyond the radiographic apex (unacceptable)</td>
</tr>
<tr>
<td>Homogeneity of the root filling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. homogeneous root filling, good condensation, no voids visible (acceptable)</td>
</tr>
<tr>
<td></td>
<td>2. inhomogeneous root filling, poor condensation, voids visible</td>
</tr>
<tr>
<td>Periapical status</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Normal: good periapical condition</td>
</tr>
<tr>
<td></td>
<td>2. Widening of the periodontal ligament not exceeding two times the width of the lateral periodontal ligament</td>
</tr>
<tr>
<td></td>
<td>3. Periapical radiolucency in connection with the apical part of the root, exceeding at least two times the width of the lateral periodontal ligament</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Only root canal fillings terminating 0-2mm from the radiographic apex and homogeneous were listed acceptable if data were grouped for further analysis

bWidening of the periodontal ligament and periapical radiolucency were pooled in the results as apical periodontitis

4.2.3. Statistical analysis

SPSS software was used for data processing and statistical analysis. $\chi^2$ test and Odds ratio were used as the univariate approach to detect statistically significant differences between groups. Logistic regression (multivariate approach) was used to
explain the periapical condition by explanatory variables. Spearman’s $r_S$ were calculated to detect correlations between clinical and radiographic parameters.

4.3. Results

A total of 745 teeth were scored clinically and radiographically in 228 subjects, i.e. an average number of 3.3 root canal treatments per subject. Two hundred and forty two (32.5%) of the teeth had signs of apical periodontitis, including 92 (12.3%) teeth exhibiting a widened apical periodontal ligament and 150 (20.1%) teeth a periapical radiolucency.

4.3.1. Coronal restoration and periapical condition

An overview of the coronal status in relation to the periapical condition is presented in Table 4-2. Seventy five percent of the coronal restorations were clinically acceptable. Radiographic signs of apical periodontitis were detected in 31.1% of those with acceptable restorations and 36.8% in teeth with unacceptable restorations; the difference was not statistically significant. This trend was repeated for the presence of marginal caries clinically as well as radiographically. When the coronal restorations were scored radiographically, 78.1% were found acceptable. Of these cases, 23.8% showed signs of apical periodontitis. Forty nine percent of the restorations scored unacceptable on radiographs were associated with signs of apical periodontitis. In this respect, the radiographic coronal parameters had a statistically significant impact on the periapical health ($\chi^2=32.027$, $p<0.001$). When the clinical and radiographic criteria for the coronal restorations were combined, the acceptable restorations (67.4% of the total) had statistically significantly less apical periodontitis than the unacceptable ones ($\chi^2=4.054$, $p<0.05$, Odds ratio: $1.008<1.392<1.921$). The Spearman $r_S$ correlation between the coronal quality of restorations scored clinically and radiographically was 0.485. For the agreement of the presence of caries scored clinically or radiographically Kappa was 0.441.
Teeth with a base material under the restorations had significantly less apical periodontitis than those without \((p<0.005)\), as did teeth restored with amalgam as compared to composite \((p<0.01)\).

4.3.2. Root canal treatment and periapical condition

Table 4-3 shows data on the quality of root canal treatment and its relation to the presence of apical periodontitis. A root canal post was present in 40.4% of teeth, but its presence had no statistically significant influence on apical periodontitis \((31.9\% \text{ vs. } 32.9\% \text{ without post})\). Forty two percent of the root canals were filled to an acceptable length \((0-2\text{mm from the radiographic apex})\), with apical periodontitis in 27.2% of cases. Of the 58.0% of teeth not filled to adequate length \((\text{short or overfilled})\), 36.4% had apical periodontitis; this difference was statistically significant \((\chi^2=6.983, p<0.01, \text{Odds ratio: } 1.115<1.531<2.103)\). The homogeneity of the root filling also had a statistically significant influence on the presence of apical periodontitis, i.e. 27.5% apical periodontitis for a homogeneous root filling as opposed to 47.1% for those that were not homogeneous \((\chi^2=99.304, p<0.001, \text{Odds ratio: } 4.595<6.898<10.354)\). There was no correlation between the length and the homogeneity of root fillings \((r_S=0.140)\). When length and homogeneity were considered, acceptable \((\text{homogeneous root filling ending 0-2mm from the radiographic apex})\) root fillings were present in only 34.4% of cases. Apical periodontitis was evident in 23.0% and 37.4% of the root fillings scored respectively as acceptable and unacceptable; this difference was statistically significant \((\chi^2=15.835, p<0.001, \text{Odds ratio: } 1.416<1.997<2.816)\).

4.3.3. Coronal restoration and root canal quality combined

The periapical condition was analysed using the logistic regression model. Table 4-4 shows the results of this analysis performed on all teeth. The following parameters had a significant influence on the periapical condition: the homogeneity of the root filling \((p<0.001)\), the radiographic appearance of the coronal restoration \((p<0.001)\) and the length of the root filling \((p<0.05)\). Table 4-5 shows the results of
the same analysis, but only on filled teeth (all crowned teeth excluded). The homogeneity of the root filling (p<0.005) and the radiographic appearance of the coronal restoration (p<0.005) also had a significant influence on the periapical condition, as well as the presence of a base (p<0.05). Table 4-6 presents the results of the combination of the parameters acceptable and unacceptable for coronal restorations and root fillings.

### Table 4-2: Quality of the coronal restoration and the relation to periapical health (n=745)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Subparameter</th>
<th>Total %</th>
<th>Periapical condition</th>
<th>Normal</th>
<th>AP</th>
<th>% AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling or crown °</td>
<td>Filling</td>
<td>55.4%</td>
<td>272</td>
<td>141</td>
<td>34.1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crown</td>
<td>40.9%</td>
<td>215</td>
<td>90</td>
<td>29.5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lost restoration</td>
<td>3.6%</td>
<td>16</td>
<td>11</td>
<td>40.7%</td>
<td></td>
</tr>
<tr>
<td>Coronal restoration (clinically) °</td>
<td>Good margin (a)</td>
<td>18.0%</td>
<td>96</td>
<td>38</td>
<td>28.4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Catching of the explorer (a)</td>
<td>43.0%</td>
<td>224</td>
<td>96</td>
<td>30.0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crevise limited to enamel (a)</td>
<td>14.2%</td>
<td>66</td>
<td>40</td>
<td>37.7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crevise penetrating to dentine (u)</td>
<td>19.3%</td>
<td>93</td>
<td>51</td>
<td>35.4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fracture of restoration (u)</td>
<td>1.2%</td>
<td>7</td>
<td>2</td>
<td>22.2%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Detached restoration (u)</td>
<td>0.7%</td>
<td>1</td>
<td>4</td>
<td>80.0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lost restoration (u)</td>
<td>3.6%</td>
<td>16</td>
<td>11</td>
<td>40.7%</td>
<td></td>
</tr>
<tr>
<td>Coronal restoration (clinically) °</td>
<td>Acceptable</td>
<td>75.2%</td>
<td>386</td>
<td>174</td>
<td>31.1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not acceptable</td>
<td>24.8%</td>
<td>117</td>
<td>68</td>
<td>36.8%</td>
<td></td>
</tr>
<tr>
<td>Marginal decay (clinically) °</td>
<td>No caries</td>
<td>81.9%</td>
<td>420</td>
<td>190</td>
<td>31.1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Caries</td>
<td>18.1%</td>
<td>83</td>
<td>52</td>
<td>38.5%</td>
<td></td>
</tr>
<tr>
<td>Coronal restoration (radiographically) °</td>
<td>Intact restoration (a)</td>
<td>78.1%</td>
<td>420</td>
<td>162</td>
<td>23.8%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Open margin (u)</td>
<td>12.3%</td>
<td>54</td>
<td>38</td>
<td>41.3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marginal decay (u)</td>
<td>9.5%</td>
<td>29</td>
<td>42</td>
<td>59.2%</td>
<td></td>
</tr>
<tr>
<td>Marginal decay (clinically or radiographically) °</td>
<td>No caries</td>
<td>79.1%</td>
<td>407</td>
<td>182</td>
<td>30.9%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Caries</td>
<td>20.9%</td>
<td>96</td>
<td>60</td>
<td>38.5%</td>
<td></td>
</tr>
<tr>
<td>Coronal restoration (clinically and radiographically) °</td>
<td>Acceptable</td>
<td>67.4%</td>
<td>351</td>
<td>151</td>
<td>30.1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unacceptable</td>
<td>32.6%</td>
<td>152</td>
<td>91</td>
<td>37.4%</td>
<td></td>
</tr>
<tr>
<td>Presence of a base *</td>
<td>No base</td>
<td>53.1%</td>
<td>131</td>
<td>92</td>
<td>41.3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Base present</td>
<td>46.9%</td>
<td>146</td>
<td>51</td>
<td>25.9%</td>
<td></td>
</tr>
<tr>
<td>Obturation material °</td>
<td>Amalgam</td>
<td>53.6%</td>
<td>161</td>
<td>64</td>
<td>28.4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Composite</td>
<td>46.4%</td>
<td>116</td>
<td>79</td>
<td>40.5%</td>
<td></td>
</tr>
</tbody>
</table>

AP: apical periodontitis
°: no statistically significant difference (p>0.05)
*: statistically significant difference (p<0.05)
(a): acceptable
(u): unacceptable
Table 4-3: Quality of the endodontic treatment and the relation to periapical health (n=745)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Subparameter</th>
<th>Total %</th>
<th>Periapical condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root canal post °</td>
<td>No post</td>
<td>59.6%</td>
<td>298</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>40.4%</td>
<td>205</td>
</tr>
<tr>
<td>Length of the root filling *</td>
<td>Good (0-2mm) (a)</td>
<td>42.0%</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td>Overfilled (u)</td>
<td>5.1%</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Underfilled (&gt;2mm) (u)</td>
<td>52.9%</td>
<td>257</td>
</tr>
<tr>
<td>Homogeneity of the root filling *</td>
<td>Homogeneous (a)</td>
<td>74.6%</td>
<td>403</td>
</tr>
<tr>
<td></td>
<td>Inhomogeneous (u)</td>
<td>25.4%</td>
<td>100</td>
</tr>
<tr>
<td>Quality of the root filling overall *</td>
<td>Acceptable</td>
<td>34.4%</td>
<td>197</td>
</tr>
<tr>
<td></td>
<td>Unacceptable</td>
<td>65.6%</td>
<td>306</td>
</tr>
</tbody>
</table>

AP: apical periodontitis
°: no statistically significant difference (p>0.05)
*: statistically significant difference (p<0.05)
(a): acceptable
(u): unacceptable

Table 4-4: Regression table of the periapical condition explained by explanatory variables (all teeth (n=745))

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Significance</th>
<th>Odds</th>
<th>95% C.I. for Odds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Homogeneity of the root filling</td>
<td>0.000</td>
<td>2.092</td>
<td>1.473</td>
</tr>
<tr>
<td>Radiographic appearance of the coronal restoration</td>
<td>0.000</td>
<td>2.673</td>
<td>1.744</td>
</tr>
<tr>
<td>Length of the root filling</td>
<td>0.046</td>
<td>1.402</td>
<td>1.006</td>
</tr>
</tbody>
</table>

Table 4-5: Regression table of the periapical condition explained by explanatory variables (filled teeth only (n=420))

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Significance</th>
<th>Odds</th>
<th>95% C.I. for Odds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Presence of a base</td>
<td>0.045</td>
<td>0.624</td>
<td>0.394</td>
</tr>
<tr>
<td>Homogeneity of the root filling</td>
<td>0.003</td>
<td>2.014</td>
<td>1.263</td>
</tr>
<tr>
<td>Radiographic appearance of the coronal restoration</td>
<td>0.002</td>
<td>2.452</td>
<td>1.390</td>
</tr>
</tbody>
</table>
Table 4-6: Periapical status of endodontically treated teeth as related to the radiographic quality of the coronal restorations combined with the quality of the root canal treatment determined by the length and homogeneity of the root filling (n=745)

<table>
<thead>
<tr>
<th>Coronal restoration</th>
<th>Endodontic treatment</th>
<th>Normal</th>
<th>AP</th>
<th>%AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCEPTABLE</td>
<td>ACCEPTABLE</td>
<td>168</td>
<td>44</td>
<td>20.8%</td>
</tr>
<tr>
<td>ACCEPTABLE</td>
<td>UNACCEPTABLE</td>
<td>252</td>
<td>118</td>
<td>31.9%</td>
</tr>
<tr>
<td>UNACCEPTABLE</td>
<td>ACCEPTABLE</td>
<td>29</td>
<td>15</td>
<td>34.1%</td>
</tr>
<tr>
<td>UNACCEPTABLE</td>
<td>UNACCEPTABLE</td>
<td>54</td>
<td>65</td>
<td>54.6%</td>
</tr>
</tbody>
</table>

AP: number of teeth with signs of apical periodontitis

Statistics (only significant combinations are listed):

A vs B: $\chi^2=8.32$, p=0.004 Odds ratio: 1.202<1.788<2.660
A vs D: $\chi^2=39.581$, p=0.000 Odds ratio: 2.815<4.596<7.504
B vs D: $\chi^2=19.865$, p=0.000 Odds ratio: 1.686<2.571<3.920
C vs D: $\chi^2=5.418$, p=0.020 Odds ratio: 1.132<2.327<4.782

Table 4-7 shows the parameters for the combined clinical and radiographic quality of the coronal restoration and for the quality of the root filling regarding length and homogeneity. When both qualities were acceptable (group A), apical periodontitis was present in 22.5% of cases. When the coronal restoration was acceptable and the endodontic treatment unacceptable (group B), 34.4% of the teeth exhibited apical periodontitis. The difference between these 2 groups was statistically significant ($\chi^2=7.743$, p<0.01, Odds ratio: 1.187<1.801<2.734). The combination of unacceptable coronal restoration and acceptable endodontic treatment (group C) resulted in a 24.3% failure rate. This was not statistically significantly different from group A, nor from group B. When the coronal restoration and the root filling were unacceptable (group D), 43.2% of the endodontically treated teeth had apical periodontitis. This was statistically significantly different from the results in groups A and C, but not from the results in group B.

Table 4-8 depicts the data on comparison of the presence of a coronal base and the quality of the root filling. When no base was placed above the root canal filling, the quality of the root filling had a statistically significant influence on the presence of apical periodontitis. In the presence of a base, there was still a difference among groups C and D, but this was not statistically significant.
Table 4-7: Periapical status of endodontically treated teeth determined by the radiographic and clinical quality of the coronal restorations combined with the quality of the root canal treatment determined by the length and the homogeneity of the root filling (n=745)

<table>
<thead>
<tr>
<th>Coronal restoration</th>
<th>Endodontic treatment</th>
<th>Normal</th>
<th>AP</th>
<th>%AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCEPTABLE</td>
<td>ACCEPTABLE</td>
<td>141</td>
<td>41</td>
<td>22.5% A</td>
</tr>
<tr>
<td>ACCEPTABLE</td>
<td>UNACCEPTABLE</td>
<td>210</td>
<td>110</td>
<td>34.4% B</td>
</tr>
<tr>
<td>UNACCEPTABLE</td>
<td>ACCEPTABLE</td>
<td>56</td>
<td>18</td>
<td>24.3% C</td>
</tr>
<tr>
<td>UNACCEPTABLE</td>
<td>UNACCEPTABLE</td>
<td>96</td>
<td>73</td>
<td>43.2% D</td>
</tr>
</tbody>
</table>

AP: number of teeth with signs of apical periodontitis
Statistics (only significant combinations are listed):
A vs B: $\chi^2=7.743$ p=0.005 Odds ratio: 1.187<1.801<2.734
C vs D: $\chi^2=7.824$ p=0.005 Odds ratio: 1.283<2.366<4.363
A vs D: $\chi^2=17.069$ p=0.000 Odds ratio: 1.647<2.615<4.151

Table 4-8: Periapical status of endodontically treated teeth determined by the presence of a base combined with the quality of the root canal treatment determined by the length and the homogeneity of the root filling (n=745)

<table>
<thead>
<tr>
<th>Coronal restoration</th>
<th>Endodontic treatment</th>
<th>Normal</th>
<th>AP</th>
<th>%AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO BASE</td>
<td>ACCEPTABLE</td>
<td>42</td>
<td>20</td>
<td>32.3% A</td>
</tr>
<tr>
<td>NO BASE</td>
<td>UNACCEPTABLE</td>
<td>89</td>
<td>72</td>
<td>44.7% B</td>
</tr>
<tr>
<td>BASE</td>
<td>ACCEPTABLE</td>
<td>46</td>
<td>10</td>
<td>17.9% C</td>
</tr>
<tr>
<td>BASE</td>
<td>UNACCEPTABLE</td>
<td>100</td>
<td>41</td>
<td>29.1% D</td>
</tr>
</tbody>
</table>

AP: number of teeth with signs of apical periodontitis
Statistics (only significant combinations are listed):
A vs B: $\chi^2=14.379$ p=0.000 Odds ratio: 1.792<3.436<6.591
B vs C: $\chi^2=12.754$ p=0.000 Odds ratio: 0.127<0.269<0.570
B vs D: $\chi^2=7.855$ p=0.005 Odds ratio: 0.314<0.507<0.818

4.4. Discussion

The design of the present study repeated that of Ray & Trope (1995), but also included the clinical evaluation of the coronal restoration. It is not possible to score the quality of a coronal restoration from a radiograph with certainty, as it provides only a two dimensional image. In the present study, only a weak correlation existed between radiographic and clinical coronal parameters ($r_S=0.485$ for quality of
restoration and $r_s=0.441$ for the presence of caries). Because of this weak correlation, the need to score restorations radiographically as well as clinically in order to assess the impact of coronal leakage was obvious. It was therefore essential to complement radiographic information with clinical data.

The current study is a cross-sectional design. It is therefore not possible to determine whether a periapical lesion is healing or expanding, though Petersson et al. (1991) found that after a 11-year period the number of healed periapical lesions was equal to the number of newly developed lesions, indicating the reliability of cross-sectional studies for scoring the long-term success of endodontic treatment. This is also supported by data from Hugoson et al. (1995).

The incidence of apical periodontitis associated with root filled teeth in this study was 32.5%. In a previous epidemiological study (Chapter 3), the incidence of apical periodontitis was 40.4%, based on panoramic radiographs. This figure is comparable to that of other studies, with data ranging from 20 to 60% (Bergström et al. 1987, Eckerbom et al. 1987, Ödesjö et al. 1990, Eriksen & Bjertness 1991, Imfeld 1991, De Cleen et al. 1993, Eriksen et al. 1995, Buckley & Spångberg 1995, Weiger et al. 1997, Saunders et al. 1997, Marques et al. 1998, Sidaravicius et al. 1999, Kirkevang et al. 2001). Seventy eight percent of the coronal restorations were found acceptable on the radiographs. This is higher than in the studies by Ray & Trope (1995, Table 4-9) (62.7%), Tronstad et al. (2000, Table 4-10) (66.2%) and Kirkevang et al. (2000) (73.5%). When the coronal restoration was scored radiographically and clinically (Table 4-2), 67.4% were found acceptable. Adequate restorations (A) showed signs of apical periodontitis in 30.1% of the teeth. This was statistically different from the 37.4% apical periodontitis in endodontically treated teeth with inadequate restorations (U). When restorations were only scored radiographically (Table 4-2), this difference was more pronounced (23.8% (A) vs. 49.1% (U)). This difference was statistically significant, as indicated by the $\chi^2$ test and the logistic regression. Other percentages were found by Tronstad et al. (2000) (respectively 30% (A) and 37% (U)) and Ray & Trope (1995) (respectively 20% (A) and 69.8% (U)) for these relationships.

In the present study, the prevalence of apical periodontitis was not influenced by the presence of a root canal post. This is in agreement with other studies (Kvist et al. 1989, Tronstad et al. 2000). Eckerbom et al. (1991) found the opposite, but their study only included crowned teeth.
### Table 4-9: Periapical status of endodontically treated teeth according to Ray & Trope 1995

<table>
<thead>
<tr>
<th>Coronal restoration</th>
<th>Endodontic treatment</th>
<th>Normal</th>
<th>AP</th>
<th>%AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCEPTABLE</td>
<td>ACCEPTABLE</td>
<td>302</td>
<td>28.5</td>
<td>8.6%</td>
</tr>
<tr>
<td>ACCEPTABLE</td>
<td>UNACCEPTABLE</td>
<td>204.5</td>
<td>98</td>
<td>32.4%</td>
</tr>
<tr>
<td>UNACCEPTABLE</td>
<td>ACCEPTABLE</td>
<td>72.5</td>
<td>92</td>
<td>55.9%</td>
</tr>
<tr>
<td>UNACCEPTABLE</td>
<td>UNACCEPTABLE</td>
<td>34</td>
<td>154</td>
<td>81.9%</td>
</tr>
</tbody>
</table>

AP: number of teeth with signs of apical periodontitis

### Table 4-10: Periapical status of endodontically treated teeth according to Trondstad et al. 2000

<table>
<thead>
<tr>
<th>Coronal restoration</th>
<th>Endodontic treatment</th>
<th>Normal</th>
<th>AP</th>
<th>%AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCEPTABLE</td>
<td>ACCEPTABLE</td>
<td>294</td>
<td>70</td>
<td>19%</td>
</tr>
<tr>
<td>ACCEPTABLE</td>
<td>UNACCEPTABLE</td>
<td>168</td>
<td>131</td>
<td>44%</td>
</tr>
<tr>
<td>UNACCEPTABLE</td>
<td>ACCEPTABLE</td>
<td>101</td>
<td>41</td>
<td>29%</td>
</tr>
<tr>
<td>UNACCEPTABLE</td>
<td>UNACCEPTABLE</td>
<td>111</td>
<td>85</td>
<td>43%</td>
</tr>
</tbody>
</table>

AP: number of teeth with signs of apical periodontitis

Root canal treatment performed to high technical standards remains a prerequisite for long-term success (Strindberg 1956, Bergenholtz (2) et al. 1979, Eckerbom et al. 1987, Ödesjö et al. 1990, Sjögren et al. 1990). Agreement exists in the literature that the length of the root filling is an important factor in endodontic treatment success (Sjögren et al. 1990, Wu et al. 2000, Chapter 3) and this is confirmed by the results of the present study. There is still some disagreement, however, about the effect of the homogeneity of the root filling on the periapical status. Ödesjö et al. (1990), Sjögren et al. (1990) and Eriksen et al. (1995) found no difference between compact and poorly compacted root fillings in relation to periapical lesions. We found the homogeneity of the root filling to have a statistically significant influence on the prevalence of apical periodontitis (Tables 4-3, 4-4 and 4-5). This is supported by others (Bergström et al. 1987, Petersson et al. 1991, Kirkevang et al. 2000).

Twenty three percent of the adequate root fillings (A) had apical periodontitis and 37.4% of the inadequate ones (U) (Table 4-3). Similar figures were presented by
Tronstad et al. (2000) (22% (A) and 44% (U) respectively). Ray & Trope (1995) (24.3% (A) and 51.4% (U) respectively) found a more pronounced difference.

As in the studies of Ray & Trope (1995) and Tronstad et al. (2000) the lowest prevalence of apical periodontitis (22.5%) was found in teeth with both an acceptable root filling and an acceptable coronal restoration (Table 4-7). A comparable figure was found when the quality of the coronal restoration was unacceptable and the quality of the root canal treatment was acceptable (24.3%). When the two groups with unacceptable endodontics were compared, there was a better result when an acceptable restoration was present, but this difference was not statistically significant. On the basis of the present data it became clear that the quality of the coronal restoration (scored clinically and radiographically) did not have statistically significant influence on the periapical status, when it was combined with the endodontic quality (Table 4-7: A vs. C and B vs. D). This is in contrast to the findings of Ray & Trope (1995). Tronstad et al. (2000) found the quality of the coronal restoration scored radiographically only to be significant when combined with acceptable endodontics.

When the endodontic status of the teeth in the present study was combined with the quality of the coronal restorations (Table 4-7: A vs. B and C vs. D), a statistically significant influence on the periapical status was seen. An explanation for the difference in findings in this study, as compared to the findings of Ray & Trope (1995) and Tronstad et al. (2000) is not obvious. In the latter studies, there was no information on the use and the influence of bases and filling materials. Coronal leakage of a restoration can be prevented by the placement of a base (Saunders & Saunders 1990, Heys and Fitzgerald 1991, Guerra et al. 1994). Our results confirm that the use of bases under coronal restorations is beneficial for the long-term outcome of root canal fillings (Tables 4-2 and 4-5). Also more apical periodontitis was detected in teeth filled with composite material than with amalgam. This was confirmed by Buckley & Spångberg (1995). Gap formation at gingival margins and subsequent bacterial colonization under the restoration is a common problem when composites are utilised (Qvist 1980, Qvist 1993, Retief 1994, Ciucchi et al. 1997).

The technical quality of a root filling, as scored on a radiograph, can be taken as an indication of the care taken for the overall quality of treatment (especially cleaning of the root canal). Canal cleanliness cannot be scored on a radiograph, although it is very important for endodontic success. Bacteria left in the root canal at

A limitation of the present and other studies remains the incomplete diagnostic value of radiographs. It is commonly known that lesions limited to the cancellous bone are almost impossible to detect with conventional radiographic techniques (Le Quire et al. 1977, Bender 1982, van der Stelt 1985), moreover, the microbiological status of the root canals cannot be derived from a radiograph.

The question remains as to how important a well sealed coronal restoration is for the long-term success of endodontic treatment. Studies by Ray & Trope (1995) and Kirkevang et al. (2000) found the coronal restoration to be of relatively greater importance than the root canal filling. Tronstad et al. (2000) found the quality of root canal treatment to be more important; the present study found both to be of equal importance. The Odds ratios in Tables 4-4 and 4-5 for the radiographic appearance of the coronal restoration and the homogeneity of the root fillings are of the same magnitude, indicating an equal effect on the periapical condition. This is in contrast with the study by Ray & Trope (1995) who found the Odds ratio for quality of restoration to be 4 times higher than for endodontic quality. Ricucci et al. (2000) found no statistically different prevalence of apical periodontitis in root fillings exposed to the oral environment compared with a control group. It is clear that bacterial ingress should be avoided, but the importance of both the coronal restoration and the root filling should be emphasized as good technical quality of both is a prerequisite for long-term success.

4.5. Conclusion

The results of this study indicate that a well sealing coronal restoration and a well-performed root canal treatment are both important for the overall success of root canal treatment. For the assessment of coronal leakage as related to apical periodontitis, radiographic evaluation of the coronal restorations is of greater importance than the quality scored only on a clinical basis. Data suggested that the problem of coronal leakage may not be of such clinical impact as indicated by previous studies, provided endodontic treatment procedures are carefully carried out.
In addition, it is clear that the use of a base under restorations is beneficial in reducing apical periodontitis.
Chapter 5
Root canal treatment performed by Flemish dentists.
Part 1. Cleaning and shaping

This chapter was published as:


ABSTRACT

Aim: The purpose of this study was to gather information on root canal treatment carried out by dentists working in Flanders (Belgium).

Methodology: A questionnaire was handed to 312 dentists attending peer review sessions organised by the Flemish Universities. Basic information (age, gender, year of graduation, practice profile) and information on various issues relating to the cleaning and shaping of root canals was collected.

Results: A total of 310 questionnaires were returned. The majority (85.7%) of respondents categorized themselves as general practitioners; 25.7% mentioned a clinical interest or speciality in practice. Most practitioners (64.5%) did not use rubber dam routinely during root canal treatment and performed treatment over 2 visits irrespective of the number of root canals. The majority of respondents (82.4%) used sodium hypochlorite as an irrigant, but 10.6% did not know the concentration they used; EDTA was used by 61.6%. The vast majority exposed a radiograph with an instrument of known length in situ to gauge the working length; only 3.6% relied on tactile sense only; electronic root canal length determination was seldom used. Among the root canal instruments K-files were used solely or in combination with other instruments by 60.3% of the respondents, reamers were used solely or in combination with other instruments by 55.4%. The stepback technique was used by 31.2% of the participants, a combination stepdown and stepback by 26.4%, a reaming technique by 26.1% and the stepdown technique by 14.7%. The majority were familiar with mechanical root canal instruments. Almost half of the practitioners believed their preparation technique could be improved; only 1.3% felt that their procedures were poor.

Conclusions: The results of this study indicate that the theoretical knowledge of dentists working in Flanders is good. However, the use of rubber dam remained low; half believed their preparation technique could be improved.
5.1.1. Introduction

Whenever postgraduate teachers discuss with practitioners the subjects they would like to see covered in courses, endodontics is often mentioned. Attendees on such courses generally wish to learn how to make endodontic treatment quicker, easier, and more successful (Carrotte (1) 2000).

It is known that the standard of root canal treatment carried out by general dental practitioners in Europe is poor (Saunders et al. 1997, Weiger et al. 1997, Marques et al. 1998, Kirkevang et al. 2001, Chapter 3, Chapter 4). It has been reported that one of the causes of such poor quality treatment in general practice may be that students graduate with a lack of expertise and a poor understanding of the principles involved (Dummer 1991). The recent European Society of Endodontology Undergraduate Curriculum Guidelines for Endodontology (European Society of Endodontology 2001) advocate that endodontics should be taught in clinical areas dedicated to that purpose, and that an appropriate number of cases should be treated. On the other hand, it could be argued that following some time in practice the clinical expertise of dentists should have improved. In the present Belgian accreditation system, where courses in different subjects of dentistry have to be followed, the number of endodontic courses (most of them combining theory and preclinical exercise) should be sufficient to improve the performance of dentists. However, there is little evidence to demonstrate whether the information gathered during these courses is used in clinical practice.

The purpose of this study was to gather information on the nature of root canal treatment carried out by a group of dentists attending peer review sessions as a part of the program of the Belgian accreditation system. Specific information regarding root canal cleaning and shaping was gathered on the basis of a questionnaire handed to dentists attending peer review sessions organised by the ‘Interuniversitaire Samenwerking’ (Inter University Cooperation of the Flemish Universities). The aim of the questionnaire was not only to collect baseline data, but also to determine the endodontic knowledge of dentists. Furthermore, it was hoped to gain an insight into potential problems regarding endodontic treatment procedures that could explain the present standard of root canal treatment carried out by general dental practitioners.
5.1.2. Methodology

A total number of 312 dentists who attended peer review sessions in the year 2000, organized by the ‘Interuniversitaire samenwerking’ (Inter University Cooperation of the Flemish Universities) i.e. the Universiteit Gent / Ghent University (UGent), the Katholieke Universiteit Leuven / Catholic University of Leuven (KULeuven), the Vrije Universiteit Brussel / Free University of Brussels (VUB), the Universiteit Antwerpen / University of Antwerp (UA, RUCA), the Limburgs Universitair Centrum (LUC), the Katholieke Universiteit Leuven Campus Kortrijk (KULAK), were asked to complete a questionnaire at the beginning of a peer review session. The questionnaires were anonymous. Of all Flemish dentists, 70% participate in peer review sessions that are part of the official accrediting system (Government figures supplied by the ‘Rijksdienst voor Ziekte- en Invaliditeitsverzekering’).

Part one of the questionnaires covered personal information: university of graduation, years of practical experience, gender, part-time or full-time occupation, and if applicable, whether a particular clinical speciality was practised.

Part two of the questionnaire covered general information regarding root canal treatment: the use of rubber dam; the number of root canal treatments per week; the number of visits for one, two, three and four canals; the frequency of treatment of the fourth canal in maxillary first molars and second molars and the frequency of C-shaped canals in mandibular molars.

In part three the practitioners were asked about their methods for cleaning and shaping canals and the products and materials used. The following topics were covered: canal irrigants and chelators, working length determination, instruments and technique used for canal preparation.

When a list of possible answers was given, the practitioners were invited to choose the answer that best fitted their clinical practice. In most of these cases the range of answers was well defined, so that there was no need to add additional responses. Space was provided when additional comments were necessary in the event of the usual practice not being adequately covered by the choice given.

The questionnaire used was tested for reliability by computing the Crohnbach alpha coefficient. For this purpose, 15 dentists were asked to complete the questionnaire with an interval of 2 months. The computed Crohnbach alpha was 0.95, indicating that the questionnaire was reliable.
One operator using Excel 2000 (Microsoft Corporation, Redmond, WA, USA) processed all questionnaires. For the detailed comparison, the sample was divided in groups according to years of practical experience or the years since graduation as follows: group 1: up to 5 years, group 2: 6 to 10 years, group 3: 11 to 15 years, group 4: 16 to 20 years, group 5: 21 to 25 years and group 6: more than 25 years. Statistical analysis was performed in SPSS 10.0 (SPSS Inc., Chicago, USA) using $\chi^2$-test and Fisher's Exact test.

5.1.3. Results

Of the 312 questionnaires distributed, only 2 were not completed, giving a completion rate of 99.4%. Three questionnaires were discarded because the respondents did not perform endodontic treatment.

5.1.3.1. General information

The majority (99.0%) of practitioners graduated from one or other of the three Flemish universities (UGent, KULeuven, VUB). Fifty one percent were males, 49% were females. Almost half the female practitioners worked part-time, whereas only a few male practitioners did. Most of the practitioners worked in full-time practice (77.2%). The distribution of the respondents by time since graduation in relation to the university of graduation is shown in Table 5-1-1.

<table>
<thead>
<tr>
<th>Dental school</th>
<th>0-5</th>
<th>6-10</th>
<th>11-15</th>
<th>16-20</th>
<th>21-25</th>
<th>&gt;25</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catholic University of Leuven</td>
<td>13</td>
<td>11</td>
<td>21</td>
<td>29</td>
<td>18</td>
<td>22</td>
<td>114 (37.1%)</td>
</tr>
<tr>
<td>Ghent University</td>
<td>12</td>
<td>23</td>
<td>21</td>
<td>28</td>
<td>28</td>
<td>24</td>
<td>136 (44.3%)</td>
</tr>
<tr>
<td>Free University of Brussels</td>
<td>10</td>
<td>15</td>
<td>12</td>
<td>9</td>
<td>4</td>
<td>4</td>
<td>54 (17.6%)</td>
</tr>
<tr>
<td>Catholic University of Louvain</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>2 (0.7%)</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>49</td>
<td>54</td>
<td>69</td>
<td>50</td>
<td>50</td>
<td>307</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>11.4%</th>
<th>16.0%</th>
<th>17.6%</th>
<th>22.5%</th>
<th>16.3%</th>
<th>16.3%</th>
</tr>
</thead>
</table>

Table 5-1-1: Distribution of the respondents according to the years of qualification and the dental school
Table 5-1-2 gives an overview of the distribution of the respondents according to their clinical speciality (preference) in practice. The majority (85.7%) of the respondents labelled themselves as general practitioners. Twenty six percent of the respondents mentioned a clinical speciality (preference) in practice. Thirty-five (11.4%) respondents were general practitioners with a special interest (Table 5-1-2). The practitioners with a true specialist practice accounted for 14.3% of the sample (44 respondents). Most practitioners reported having no special clinical interest in their practice (74.3%).

<table>
<thead>
<tr>
<th>Clinical Interest</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>General practitioner</td>
<td>263</td>
<td>85.7%</td>
</tr>
<tr>
<td>General practitioner not reporting special clinical interest</td>
<td>228</td>
<td>74.3%</td>
</tr>
<tr>
<td>General practitioner reporting special clinical interest</td>
<td>35</td>
<td>11.4%</td>
</tr>
<tr>
<td>Endodontics</td>
<td>6</td>
<td>2.0%</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>7</td>
<td>2.3%</td>
</tr>
<tr>
<td>Orthodontics</td>
<td>13</td>
<td>4.2%</td>
</tr>
<tr>
<td>Periodontics</td>
<td>3</td>
<td>1.0%</td>
</tr>
<tr>
<td>Paediatric dentistry</td>
<td>5</td>
<td>1.6%</td>
</tr>
<tr>
<td>Prosthodontics</td>
<td>10</td>
<td>3.3%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>0.7%</td>
</tr>
<tr>
<td>Specialist practice</td>
<td>44</td>
<td>14.3%</td>
</tr>
<tr>
<td>Endodontics</td>
<td>4</td>
<td>1.3%</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>6</td>
<td>2.0%</td>
</tr>
<tr>
<td>Orthodontics</td>
<td>10</td>
<td>3.3%</td>
</tr>
<tr>
<td>Periodontics</td>
<td>6</td>
<td>2.0%</td>
</tr>
<tr>
<td>Paediatric dentistry</td>
<td>15</td>
<td>4.9%</td>
</tr>
<tr>
<td>Prosthodontics</td>
<td>12</td>
<td>3.9%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

5.1.3.2. General information about endodontic treatment

5.1.3.2.1. Rubber dam

The majority (64.5%) of individuals never or seldom used rubber dam, 20.5% of the sample used rubber dam in a limited number of cases and only 7.2% used
rubber dam in all cases. The time since graduation had no statistically significant effect \((p=0.054, \chi^2=18.1)\) on use of rubber dam.

5.1.3.2.2. Frequency of root canal treatment and number of visits per treatment

The number of root canal treatments performed in 1 week ranged from 1 to 9, with an average of 4.8 and a mode of 7 (Table 5-1-3). There was no statistically significant influence of the period since qualification on the number of root canal treatments performed per week.

<table>
<thead>
<tr>
<th>Period following qualification</th>
<th>RCT per week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>No answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6-10</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td>11</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11-15</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>18</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>16-20</td>
<td>2</td>
<td>5</td>
<td>12</td>
<td>6</td>
<td>3</td>
<td>14</td>
<td>18</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>21-25</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>11</td>
<td>5</td>
<td>4</td>
<td>10</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>&gt; 25</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>8</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>17</td>
<td>32</td>
<td>44</td>
<td>38</td>
<td>30</td>
<td>49</td>
<td>69</td>
<td>19</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

A summary of the number of average visits mentioned to complete treatment in relation to the number of root canals in a tooth is depicted in Figure 5-1-1. There was a clear trend towards more visits when more canals were to be treated. Most root canal treatments were performed within 2 visits, even for single rooted teeth. There were no statistically significant differences between the different periods following graduation and the number of visits taken to complete a root filling.

5.1.3.2.3. Anatomical variations

The percentage of fourth canals (second mesiolabial canal) treated in maxillary first and second molars and C-shaped root canal system treated in mandibular molars is described in Table 5-1-4. The majority of the respondents seldom treated the second mesiolabial canal in maxillary molars, nor were aware of
C-shaped mandibular first molars. Approximately 18% of the respondents did not respond to the question concerning C-shaped mandibular molars.

![Figure 5-1-1: Number of visits according to the number of treated root canals per tooth](image)

<table>
<thead>
<tr>
<th>Prevalence (%)</th>
<th>Number of respondents scoring the prevalence of Four canals in maxillary first molar</th>
<th>Four canals in maxillary second molar</th>
<th>C-shaped canal in mandibular molar</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25</td>
<td>279</td>
<td>291</td>
<td>238</td>
</tr>
<tr>
<td>0</td>
<td>18</td>
<td>84</td>
<td>45</td>
</tr>
<tr>
<td>1</td>
<td>67</td>
<td>91</td>
<td>61</td>
</tr>
<tr>
<td>2-5</td>
<td>87</td>
<td>69</td>
<td>65</td>
</tr>
<tr>
<td>6-10</td>
<td>62</td>
<td>35</td>
<td>37</td>
</tr>
<tr>
<td>11-20</td>
<td>24</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>21-25</td>
<td>21</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>26-50</td>
<td>11</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>51-75</td>
<td>8</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>76-100</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>No answer</td>
<td>6</td>
<td>11</td>
<td>54</td>
</tr>
</tbody>
</table>
5.1.3.3. Cleaning and shaping

5.1.3.3.1. Irrigation and medication

Sodium hypochlorite was the most popular choice as a canal irrigant with 82.4% of the respondents using it during treatment; of that total 70.4% used only sodium hypochlorite, whereas 29.6% used it along with other irrigants. The irrigants used besides sodium hypochlorite were chloramine (16.6%), chlorhexidine (7.5%), distilled water (2.6%), hydrogen peroxide (11.1%) and saline (6.8%). The time since graduation did not statistically significantly influence the choice of the irrigant. The most popular concentration of sodium hypochlorite was 2.5% (39.1% of respondents that used sodium hypochlorite), with 2% using a 0.5% solution, 3.6% using 1%, 4.9% using 1.5%, 22.1% using 2%, and 9.1% using 5%. Of the respondents that used sodium hypochlorite, 10.6% did not answer or did not know the concentration of sodium hypochlorite they used. Seven percent used two or more concentrations. Of the practitioners irrigating root canals with sodium hypochlorite, 68.9% never used rubber dam, 22.3% used rubber dam in a limited number of cases and 8.8% used rubber dam in all cases.

EDTA was used by 61.6% of the respondents, in a variety of formulations. A liquid EDTA solution was used by 12.4%, File-Eze (Ultradent Products Inc., South Jordan, UT, USA) by 13.4%, Rc-prep (Premier Dental Products Co., King of Prussia, PA, USA) by 32.9% and 7.2% used other formulations. Of the practitioners that used EDTA, 87.8% combined the chelator with sodium hypochlorite. There was no significant relationship between the use of EDTA and the time after graduation.

5.1.3.3.2. Working distance

Most practitioners used radiographs for length determination. The most common apical limit of preparation was 1mm short of the radiographic apex (44.3%), followed by 0.5mm short of the radiographic apex (19.9%). Only 1.6% of respondents used a working distance 0.5mm beyond the radiographic apex, whilst 16.9% prepared as far as the radiographic apex. An apical terminus located 1.5mm short of the radiographic apex was chosen by 16.0% of the practitioners and only 3.9% ended the canal preparation 2 to 3mm short of the radiographic apex.
A small proportion (3.6%) relied on tactile sense for length determination; all of these had graduated for longer than 10 years. The use of electronic apex locators was limited with 16.0% of the practitioners using it occasionally and 4.9% seldomly. Approximately 80% of the respondents never used electronic length determination. There was no statistically significant difference in the use of electronic apex locators in relation to the time after graduation.

5.1.3.3.3. Instruments

Table 5-1-5 gives an overview of the hand instruments used for preparation of the root canal by time since qualification. Overall, K-files were the most popular instruments. Root canal preparation solely with K-files or in combination with other instruments was performed by 60.3% of the respondents, followed by 55.4% that used reamers (solely or in combination), H-files (solely or in combination) by 46.9% of the respondents and 19.2% of the respondents combined K-files and reamers during root canal preparation. Ni-Ti hand files were used by 49.5% of the practitioners. There was a statistically significant difference in usage of instruments as related to the time after graduation ($p=0.039$, $\chi^2=44.9$). The older practitioners tended to use reamers more than their younger colleagues.

Table 5-1-5: Number of respondents using the various endodontic instruments by time since graduation

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Years of qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-5</td>
</tr>
<tr>
<td>Reamer</td>
<td>2</td>
</tr>
<tr>
<td>K-file</td>
<td>11</td>
</tr>
<tr>
<td>H-file</td>
<td>3</td>
</tr>
<tr>
<td>Reamer + K-file</td>
<td>2</td>
</tr>
<tr>
<td>Reamer + H-file</td>
<td>3</td>
</tr>
<tr>
<td>K-file + H-file</td>
<td>6</td>
</tr>
<tr>
<td>Reamer + K-file + H-file</td>
<td>6</td>
</tr>
<tr>
<td>No answer</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
</tr>
</tbody>
</table>
5.1.3.3.4. Rotary instruments

Engine driven instruments were used by 27.7% of the respondents. There was no difference between the different qualification-time groups regarding the frequency of use of engine driven instruments.

The practitioners were familiar with the following instruments: Profile (Dentsply-Maillefer, Ballaigues, Switzerland) (71.3%), Ultrasonic files (53.4%), Files of Greater Taper (Dentsply Tulsa Dental, Tulsa, OH, USA) (39.1%), Safety H-files (Kerr-Sybron, West Collins Orange, CA, USA) (30.9%), Lightspeed (Lightspeed Technology Inc., San Antonio, TX, USA) (10.7%) and Quantec (Sybron endo, West Collins Orange, CA, USA) (3.6%).

Of the respondents, 72.4% used only hand files for root canal preparation, 26.0% used a combination of hand files and rotary instruments and 1.6% used only rotary instruments.

5.1.3.3.5. Preparation techniques

Table 5-1-6 gives an overview of the instruments used by the different preparation techniques. Almost one third of the practitioners (31.9%) stated that they used the stepback technique, followed by 26.4% for the combination of stepdown and stepback and 26.1% for a reaming technique. The stepdown technique was used by 14.7% of the respondents. The technique used differed significantly between the qualification-time groups (p< 0.05). Reaming was used more by the older practitioners (group 4); stepback and stepdown were used equally by all age groups.

The relation between the technique used to prepare the root canal and the number of root canal treatments performed per week is described in Table 5-1-7. There were no statistically significant differences between the preparation techniques and the number of root canals per week.

The questionnaire also requested whether the following techniques were known by the respondents (positive responses between parentheses): crown-down (45.0%), balanced force or Roane technique (31.6%), crown-down pressureless technique (20.2%) and modified double flared technique (19.5%). There were no statistically significant differences between the different qualification-time groups regarding knowledge of these techniques.
Table 5-1-6: Number of respondents using the various endodontic instruments by preparation techniques

<table>
<thead>
<tr>
<th>Endodontic instruments</th>
<th>Reaming</th>
<th>Stepback</th>
<th>Stepdown</th>
<th>Stepdown + stepback</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reamer</td>
<td>9</td>
<td>10</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>K-file</td>
<td>1</td>
<td>19</td>
<td>12</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>H-file</td>
<td>7</td>
<td>13</td>
<td>1</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Reamer + K-file</td>
<td>24</td>
<td>13</td>
<td>5</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Reamer + H-file</td>
<td>22</td>
<td>16</td>
<td>4</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>K-file + H-file</td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Reamer + K-file + H-file</td>
<td>13</td>
<td>16</td>
<td>7</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>No answer</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>80</td>
<td>98</td>
<td>45</td>
<td>81</td>
<td>10</td>
</tr>
<tr>
<td><strong>26.1%</strong></td>
<td><strong>31.9%</strong></td>
<td><strong>14.7%</strong></td>
<td><strong>26.4%</strong></td>
<td><strong>3.3%</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 5-1-7: Distribution of the respondents by number of root canal treatments (RCT) performed per week and the preparation technique

<table>
<thead>
<tr>
<th>Preparation technique</th>
<th>RCT per week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaming</td>
<td></td>
<td>1</td>
<td>6</td>
<td>16</td>
<td>11</td>
<td>7</td>
<td>14</td>
<td>18</td>
<td>3</td>
<td>1</td>
<td>77</td>
</tr>
<tr>
<td>Stepback (SB)</td>
<td></td>
<td>2</td>
<td>17</td>
<td>13</td>
<td>12</td>
<td>7</td>
<td>15</td>
<td>20</td>
<td>9</td>
<td>1</td>
<td>96</td>
</tr>
<tr>
<td>Stepdown (SD)</td>
<td></td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>3</td>
<td>10</td>
<td>11</td>
<td>2</td>
<td>1</td>
<td>43</td>
</tr>
<tr>
<td>SB + SD</td>
<td></td>
<td>3</td>
<td>8</td>
<td>13</td>
<td>6</td>
<td>11</td>
<td>11</td>
<td>22</td>
<td>6</td>
<td>1</td>
<td>81</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A large proportion (44.3%) of the respondents were satisfied with the preparation technique (rotary or hand instrumentation) they used in daily practice, 48.2% felt that their root canal preparations could be improved and 1.3% was completely dissatisfied with their root canal preparations.

5.1.4. Discussion

All persons participating in this study were attending a formal peer review session. These peer review activities are part of an accreditation system, in which 70% of the Flemish practitioners take part. The distribution of the age groups reflected the age distribution of the Flemish dental profession, with the greater
number of graduates in the 1980s. Therefore, the group selected is likely to be representative of the general dental population in the Flemish part of Belgium. The group was represented by graduates from all Flemish universities.

The response rate was high, which would be expected when questionnaires are handed out personally and collected immediately after completion. This is in contrast with postal surveys where the response rates are generally lower. The majority of the respondents were general practitioners (85.7%), reflecting the fact that this is the area where the majority of dental treatment is provided in Belgium.

The use of rubber dam by Belgian dental practitioners was low. Only 7% of the practitioners used rubber dam in all cases, even though the use of rubber dam is taught in every dental school in Flanders. These results agree with other recent studies (Saunders et al. 1999, Whitworth et al. 2000, Jenkins et al. 2001). There was no relation between the use of rubber dam and the time after graduation, indicating that its use in daily dental practice is abandoned quickly following graduation.

The majority of root canal treatments was carried out in 2 visits, even for teeth with single root canals. Similar results were found by Saunders et al. (1999) who studied general dental practitioners in Great Britain and Inamoto et al. (2002) with questionnaires sent to endodontists in the USA. The increased number of visits necessary for the treatment of multiple canals reflected the complexity of treating such cases. The number of appointments required for treatment is a matter of debate. One visit root canal treatment is not encouraged for necrotic pulps (Sjögren et al. 1997, Trope et al. 1999), however, it could be argued that with more visits, the risk of contamination increases, i.e. especially in these cases over two visits.

The majority of practitioners did not treat the fourth canal in maxillary first and second molars, even though it may be present in at least 60% of the maxillary first and second molars (Okumura 1927, Kulild & Peters 1990). Furthermore, approximately one fifth of the respondents did not respond to the question on treating a C-shape in mandibular molars. We assume that the majority of the present practitioners were not aware of the true meaning of the C-shape in mandibular molars. A C-shaped root canal system is present in approximately 8% of the mandibular second molars (Cooke & Cox 1979, Weine 1998). The practitioners indicating treatment of C-shapes in over 50% probably had misinterpreted the question and saw the C-shape as a kidney-shaped distal canal in lower molars. This
became clear when the subject of C-shapes was discussed during the peer review sessions.

In this study sodium hypochlorite was most popular among most of the practitioners; in concentrations up to 5%, it was used in 82.4% of cases. Sodium hypochlorite combined with hydrogen peroxide and chlorhexidine has been described in the literature (Ingle & Bakland 1994) although the combination of sodium hypochlorite and hydrogen peroxide is not recommended (Harrison et al. 1978). Furthermore, the use of irrigants such as chloramine and saline are not recommended for endodontic use (Ingle & Bakland 1994, Heling & Chandler 1998) as they do not have the antimicrobial and tissue solvi ng capacities of a sodium hypochlorite solution. A possible reason for not using sodium hypochlorite and using a weak solution may be related to the limited use of rubber dam (Saunders et al. 1999, Whitworth et al. 2000, Jenkins et al. 2001), but was not the case in the present study.

Correct estimation of the length of the root canal is essential and this can be established by tactile sense, using radiographs and/or by electronic devices. Radiographs with an instrument of known length in situ were used for length determination by virtually all respondents. Only a minority (3.5%) relied on tactile sense for estimation of the working length. This method is not recommended since it does not give reliable results due to anatomical obstructions and constrictions in the canals (Dummer 1984). There was no subdivision in the question concerning the influence of tooth vitality (vital versus necrotic pulps), but the results indicated that the majority of the respondents was aiming for a working length 1 to 2mm short of the radiographic apex. Recent advances in endodontics have led to improved reliability of electronic length determination (De Moor et al. 1999). However, these devices were not often used (20%).

K-files were the hand instruments of choice for root canal preparation for most of the practitioners. They were used solely or in combination with other root canal instruments. Reamers, although abandoned by many schools for routine preparation, were still used by more than half of the practitioners; H-files and Ni-Ti files were also widely used.

Ingle (1961) described a standardized method for root canal instrumentation and preparation, utilizing instruments of fixed size and taper, with matching points for obturation. This technique was taught widely and is known to be widely practised.
Although he did not actually use the term ‘stepback’, Schilder (1974) described the sequential widening of the apical part of the canal and the technique was rapidly adopted and further developed. The data in the present study showed that a great number of the older practitioners still used the standardized method, though it was interesting to see that the stepback technique with or without orifice enlargement was well established. This finding is in contrast with the findings of Jenkins et al. (2001), who showed that in their study practitioners tended to use the technique they were taught. Apparently, the stepdown / stepback approach, which is taught at the Flemish universities during present-day undergraduate programs and during postgraduate courses, was adopted by the majority of the practitioners participating in this study. Preparation techniques such as the crown-down technique, balanced force technique, crown-down pressureless technique or modified double flared technique were not commonly used and were only known by a minority of the practitioners. This finding emphasises the need for continuing postgraduate training in endodontics.

About one third of the respondents were familiar with the more modern preparation techniques but it was clear that each of the presently available systems was different, with various techniques and products. In this respect, an interesting finding was that about half of the respondents felt their root canal preparation could be improved. A small minority were dissatisfied with the result of the preparation technique.

5.1.5. Conclusion

It is clear that a large percentage of dentists irrespective of the time since graduation relied on techniques and used products and materials which are currently favoured by expert opinion. Nonetheless, half of the present group seemed not to be satisfied with their preparation technique.

5.1.5. Conclusion
5.1.6. Acknowledgements

We wish to gratefully acknowledge the effort of all collaborators of the 'Interuniversitaire Samenwerking' and the campus-coordinators (Prof. M. Braem, Prof. P. Bottenberg, Prof. G. Van Herle, Prof. M. Van Herle and Prof. B. De Mot) for their support in this project.
Chapter 5

Root canal treatment performed by Flemish dentists.

Part 2. Canal filling and decision making for referrals and treatment of apical periodontitis

This chapter was published as:

G.M.G. Hommez, R.J.G. De Moor, M. Braem. Root canal treatment performed by Flemish dentists. Part 2. Canal filling and decision making for referrals and treatment of apical periodontitis.
ABSTRACT

Aim: To gather information on root canal treatment carried out by dentists working in Flanders (Belgium).

Methodology: A questionnaire reported in a previous study was also used to gather information on canal medicaments, canal filling, and on decision making for referrals and treatment of apical periodontitis.

Results: Calcium hydroxide as an interappointment dressing was used by 69.7% of the respondents. Approximately one third of the respondents did not use any intra-canal medicament. Caustic products used for pulp tissue fixation were used by 66.8% of the respondents. Cavit® (48.2%) and glass-ionomer (31.3%) were the temporary coronal filling materials used most often, followed by zinc oxide eugenol and IRM®. Cold lateral condensation of gutta percha was the filling technique most used by the respondents (65.8%). Single cone gutta percha placement (16%), paste techniques (4.9%) and silver points (3.9%) were still used. Resin based sealers were used most often (88.6%). Paraformaldehyde containing sealers such as Endomethasone and N2 were used infrequently. Approximately half of the practitioners were satisfied with their canal filling technique, the others felt they could do better (43.0%); 0.7% were not satisfied. In cases with apical periodontitis the size of periapical lesions and/or the presence of a root filling influenced the choice of endodontic treatment. The most common reasons for referral of endodontic cases were: retrieval of silver points, surgery and post removal.

Conclusions: The results of this study indicate that techniques and methods used for canal medication and canal filling were acceptable for the majority of the respondents. Retreatment was underestimated as a treatment option.
5.2.1. Introduction

In the first part of this study (Chapter 5, Part 1) the opinions and views of a group of Flemish dentists regarding cleaning and shaping canals during root canal treatment were reported.

The objective of root filling is to prevent passage of micro-organisms and fluid between the canal system and periradicular tissue (European Society of Endodontology 1994). Unfortunately, longitudinal studies of endodontic treatment in general dental practice have shown large numbers of teeth with inadequate root fillings associated with periradicular disease. This inevitably results in a growing demand for further treatment. Retreatment is clearly indicated when a periapical lesion, clinical signs or symptoms are present (Friedman & Stabholz 1986). Despite guidelines provided to simplify endodontic retreatment decision making (European Society of Endodontology 1994, American Association of Endodontists 1998), large intra- and inter-individual discrepancies remain in the estimation of endodontic retreatment requirements (Aryanpour et al. 2000, McCaul et al. 2001). The complexity of the operative procedures and the variety of treatment alternatives introduce variation into the choice of therapy (Kvist et al. 1994). It has also been shown that decision making depends on the technical problems encountered and the clinical experience, confidence and training of general practitioners (Reit et al. 1985, Reit & Gröndahl 1987). In this respect it is also of interest to understand how practitioners deal with apical periodontitis and which cases are referred to endodontists for speciality treatment.

The first aim of this study was to gather information on root canal filling, carried out by a group of dentists attending peer review sessions as a part of the program of the Belgian accreditation system. Specific information was obtained on the basis of a questionnaire handed to dentists at these sessions organised by the ‘Interuniversitaire Samenwerking’ (Interuniversity Cooperation of the Flemish Universities) (Chapter 5, part 1). The aim of the questionnaire was not only to collect baseline data, but also to get an inventory of the present level of endodontic knowledge and on potential problems regarding endodontic treatment procedures.
The second aim of the study was to gain insight into endodontic treatment decision made in relation to periapical pathology and root canal status and to make an inventory of cases considered for referral.

5.2.2. Materials and methods

The information for this study was gathered through the second part of the questionnaire used in a previous study (Chapter 5, part 1).

The present study deals with questions on canal medicaments and access cavities. In addition, information was gathered on filling techniques, sealers and use of caustic products. Decision making of dental practitioners regarding referrals and treatment options when confronted with periapical lesions of different size were also investigated.

5.2.3. Results

Of the 312 questionnaires distributed, only 2 were not completed, giving a total of 99.4% completion; three questionnaires were discarded because the respondents did not perform endodontic treatment. In all, 307 questionnaires (98.4%) were analysed in this study.

5.2.3.1. Intracanal medication and temporary coronal filling material

Calcium hydroxide was used as an interappointment medicament by 69.7% of the practitioners. Approximately one third (29.6%) of the practitioners did not use any dressing. Other not specified intracanal medicaments were used by 6.8% of the practitioners. The use of calcium hydroxide by year of graduation of the respondents is given in Table 5-2-1. There was no statistically significant difference between the age groups (p>0.05), although there was a trend towards reduced use in the older age groups of the dentists.

Table 5-2-2 describes the use of caustic products in root canal treatment by the respondents. These chemicals were used by 66.8% of the respondents;
Rockless® (Spécialités Septodont, Saint – Maur – des Fossés, France) was used by most (34.2%) followed by Tempofore® (Spécialités Septodont) (26.4%). The preparation containing arsenic (Caustinerf Arsenic®) was used by 2.3% of the respondents. There was no statistically significant difference between the different graduation groups (time since graduation) as related to the use of caustic products (p>0.05).

<table>
<thead>
<tr>
<th>Graduation group (years)</th>
<th>Ca(OH)₂ Total in group</th>
<th>% Ca(OH)₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>6-10</td>
<td>37</td>
<td>49</td>
</tr>
<tr>
<td>11-15</td>
<td>39</td>
<td>54</td>
</tr>
<tr>
<td>16-20</td>
<td>44</td>
<td>69</td>
</tr>
<tr>
<td>21-25</td>
<td>31</td>
<td>50</td>
</tr>
<tr>
<td>&gt;25</td>
<td>35</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 5-2-1: Use of calcium hydroxide related to the time since graduation

Table 5-2-3 summarizes the materials used for temporary filling of access cavities. Cavit® (ESPE, Neus, Germany) was used by 48.2% of the respondents, followed by glass-ionomer (31.3%), zinc oxide eugenol (27.0%) and IRM® (Dentsply De Trey, Konstanz, Germany) (15.3%). Resin composite (1.6%) and amalgam (1.6%) were seldom used and other unspecified materials were used by 5.2% of the respondents. The time since graduation had no statistically significant influence (p>0.05) on the choice of temporary filling material.

5.2.3.2. Filling of the root canal

The different techniques used by the respondents to fill root canals are listed in Table 5-2-4. Cold lateral condensation of gutta percha was the technique used by most respondents (65.8%). The other techniques were used infrequently (in descending order): single cone gutta percha (16.0%), Thermafil® (Maillefer, Ballaigues, Switzerland) (12.4%), vertical condensation (11.7%), warm lateral condensation (10.1%), thermomechanical compaction of gutta percha (5.5%), paste
### Table 5-2-2: Caustic products used during root canal therapy according to the period since qualification

<table>
<thead>
<tr>
<th>Product</th>
<th>Main toxic components</th>
<th>Period since qualification</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-5</td>
<td>6-10</td>
<td>11-15</td>
</tr>
<tr>
<td>Caustinerf arsenic®</td>
<td>30% arsenicum anhydride</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Caustinerf non-arsenic®</td>
<td>46% paraformaldehyde</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Pulpery®</td>
<td>29% creosote</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Toxavit®</td>
<td>30-50% paraformaldehyde</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rockless®</td>
<td>32% formaldehyde</td>
<td>14</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>CHKM®</td>
<td>27% chlorophenol</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Créosophè®</td>
<td>30% paramonochlorophenol</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Tempofore®</td>
<td>12.6% iodoform + 1-5% creosote</td>
<td>13</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>None</td>
<td></td>
<td>10</td>
<td>16</td>
<td>22</td>
</tr>
</tbody>
</table>

Caustinerf arsenic®, Caustinerf non-arsenic®, Pulpery®, Rockless®, Créosophè®, Tempofore®: Spécialités Septodont, Saint – Maur – des Fossés, France
Toxavit®: Lege artis Pharma GmbH, Dettenhausen, Germany
CHKM®: Spécialités Septodont, Saint – Maur – des Fossés, France
technique (4.9%), silver points (3.9%) and Soft-Core® (Soft-Core DP APS, Copenhagen, Denmark) (0.7%). Cold lateral condensation was used by 82.9% of the respondents who had graduated in the latest 5 years (Table 5-2-5). This percentage dropped with the time since graduation to 48.0% of the respondents who had graduated more than 25 years. Conversely the use of gutta percha single cone techniques and pastes increased with age.

Table 5-2-6 lists the root canal sealers used by the respondents. AH-plus® (Dentsply De Trey) was used by 37.8% of the respondents followed by 34.5% for AH-26® (Dentsply De Trey). The other sealers listed in descending order of preference were: Topseal® (Maillefer) (16.3%), Sealapex® (Kerr Corporation, Orange, Ca, USA) (15.0%), Endomethasone® (Spécialités Septodont, Saint – Maur – des Fossés, France) (11.7%), Tubliseal® (Kerr Corporation) (11.7%), Zinc oxide eugenol (7.2%), N2® (Hager & Werken GmbH, Duisburg, Germany) (2.0%), Ketac-Endo® (ESPE) (1.0%) and Grossman’s sealer® (Cartensen, Medex Omicron, Buenos Aires, Argentina) (0.7%). Table 5-2-7 describes the root canal sealers used in relation to the obturation technique.

Nearly half the respondents (48.9%) were satisfied with their filling technique, 43.0% felt that they could perform better, 0.7% were not satisfied and 7.5% did not answer the question.
<table>
<thead>
<tr>
<th>Technique</th>
<th>0-5</th>
<th>6-10</th>
<th>11-15</th>
<th>16-20</th>
<th>21-25</th>
<th>&gt;25</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold lateral condensation</td>
<td>29</td>
<td>35</td>
<td>39</td>
<td>45</td>
<td>30</td>
<td>24</td>
<td>202</td>
<td>65.8</td>
</tr>
<tr>
<td>Single cone gutta percha</td>
<td>1</td>
<td>4</td>
<td>9</td>
<td>16</td>
<td>7</td>
<td>12</td>
<td>49</td>
<td>16.0</td>
</tr>
<tr>
<td>Thermafil®</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>38</td>
<td>12.4</td>
</tr>
<tr>
<td>Vertical condensation</td>
<td>5</td>
<td>3</td>
<td>10</td>
<td>8</td>
<td>4</td>
<td>6</td>
<td>36</td>
<td>11.7</td>
</tr>
<tr>
<td>Warm lateral condensation</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>31</td>
<td>10.1</td>
</tr>
<tr>
<td>Thermomechanical gutta percha compaction</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>17</td>
<td>5.5</td>
</tr>
<tr>
<td>Paste technique</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>15</td>
<td>4.9</td>
</tr>
<tr>
<td>Silver point</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>12</td>
<td>3.9</td>
</tr>
<tr>
<td>Soft-Core®</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Thermafil®: Maillefer, Ballaigues, Switzerland
Soft-Core®: Soft-Core DP APS, Copenhagen, Denmark
Table 5-2-5: Root canal obturation technique related to the time since graduation

<table>
<thead>
<tr>
<th>Root canal obturation technique</th>
<th>0-5</th>
<th>6-10</th>
<th>11-15</th>
<th>16-20</th>
<th>21-25</th>
<th>&gt;25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold lateral condensation</td>
<td>29 (82.9%)</td>
<td>35 (71.4%)</td>
<td>38 (70.4%)</td>
<td>46 (66.7%)</td>
<td>30 (60.0%)</td>
<td>24 (48.0%)</td>
</tr>
<tr>
<td>Single cone gutta percha</td>
<td>1</td>
<td>4</td>
<td>9</td>
<td>16</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Thermafil®</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>5</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Vertical condensation</td>
<td>5</td>
<td>3</td>
<td>10</td>
<td>8</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Warm lateral condensation</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Thermomechanical gutta percha compaction</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Paste technique</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Silver point</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Soft Core®</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 5-2-6: Root canal sealers used by the respondents

<table>
<thead>
<tr>
<th>Root canal sealer</th>
<th>Type of root canal sealer</th>
<th>Number of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH-plus®</td>
<td>Epoxy resin sealer</td>
<td>116</td>
<td>37.8</td>
</tr>
<tr>
<td>AH-26®</td>
<td>Epoxy resin sealer</td>
<td>106</td>
<td>34.5</td>
</tr>
<tr>
<td>Topseal®</td>
<td>Epoxy resin sealer</td>
<td>50</td>
<td>16.3</td>
</tr>
<tr>
<td>Sealapex®</td>
<td>Resin and calcium hydroxide sealer</td>
<td>46</td>
<td>15.0</td>
</tr>
<tr>
<td>Endomethasone®</td>
<td>ZOE sealer + paraformaldehyde + dexamethasone</td>
<td>36</td>
<td>11.7</td>
</tr>
<tr>
<td>Tubiseal®</td>
<td>ZOE sealer</td>
<td>36</td>
<td>11.7</td>
</tr>
<tr>
<td>Zinc oxide eugenol</td>
<td>ZOE sealer</td>
<td>22</td>
<td>7.2</td>
</tr>
<tr>
<td>N2®</td>
<td>ZOE sealer + paraformaldehyde</td>
<td>6</td>
<td>2.0</td>
</tr>
<tr>
<td>Ketac-Endo®</td>
<td>Glass-ionomer sealer</td>
<td>3</td>
<td>1.0</td>
</tr>
<tr>
<td>Grossman's sealer®</td>
<td>ZOE sealer</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>5</td>
<td>1.6</td>
</tr>
</tbody>
</table>

AH-plus®, AH-26®: De Trey Dentsply, Konstanz, Germany
Topseal®, Maillefer, Ballaigues, Switzerland
Sealapex®, Tubiseal®: Kerr Corporation, Orange, Ca, USA
Endomethasone®, Spécialités Septodont, Saint – Maur – des Fossés, France
N2®: Hager & Werken GmbH, Duisburg, Germany
Ketac-Endo®, ESPE, Neus, Germany
Grossman's sealer®, Cartensen, Medex Omicron, Buenos Aires, Argentina

5.2.3.3. Endodontic (re)treatment decision making

Four out of five respondents performed root canal retreatments. The following solvents were used in descending order: chloroform (36.5%), Endosolv E® (Spécialités Septodont) (8.8%), Endosolv R® (Spécialités Septodont) (5.2%), turpentine (4.2%), other not specified solvents were used by 3.9%. One quarter of the respondents (25.4%) never used solvents during endodontic retreatment.

The respondents were asked to rate their attitude towards referring endodontic cases on a scale from 1 to 10. A score of one meant the practitioner did not refer, whilst 10 meant the practitioner was enthusiastic about endodontic referral. The majority rated between 1 and 5 (64.5%); only 35.5% rated endodontic referral more than 5.

Table 5-2-8 gives an overview on treatment decision making in specific situations. When no root filling was present and a periapical lesion less than 1 cm wide was seen on a radiograph, the majority of the respondents (90.9%) performed conventional root canal treatment in one or more visits. If the periapical lesion, in absence of a root filling, was wider than 1 cm, the number of respondents that chose
<table>
<thead>
<tr>
<th>Root canal obturation technique</th>
<th>Root canal sealer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AH-plus®</td>
</tr>
<tr>
<td>Cold lateral condensation</td>
<td>89</td>
</tr>
<tr>
<td>Single cone gutta percha</td>
<td>14</td>
</tr>
<tr>
<td>Thermafil®</td>
<td>15</td>
</tr>
<tr>
<td>Vertical condensation</td>
<td>15</td>
</tr>
<tr>
<td>Warm lateral condensation</td>
<td>14</td>
</tr>
<tr>
<td>Thermomechanical gutta percha compaction</td>
<td>9</td>
</tr>
<tr>
<td>Paste technique</td>
<td>7</td>
</tr>
<tr>
<td>Silver point</td>
<td>4</td>
</tr>
<tr>
<td>Soft-Core®</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>
In addition, more respondents chose conventional root canal treatment followed by an apicectomy (26.4%), referral to an endodontist (18.2%), and extraction (8.5%) as a treatment option.

Table 5-2-8: Endodontic (re)treatment decision making in relation to periapical pathology and root canal status

<table>
<thead>
<tr>
<th>Treatment chosen</th>
<th>No root filling</th>
<th>Root filling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Periapical lesion &lt; 1 cm</td>
<td>Periapical lesion &gt; 1 cm</td>
</tr>
<tr>
<td>Root canal treatment</td>
<td>279 (90.9%)</td>
<td>176 (57.3%)</td>
</tr>
<tr>
<td>Root canal treatment + apicectomy</td>
<td>17 (5.5%)</td>
<td>81 (26.4%)</td>
</tr>
<tr>
<td>Apicectomy</td>
<td>7 (2.3%)</td>
<td>13 (4.2%)</td>
</tr>
<tr>
<td>Extraction</td>
<td>3 (1.0%)</td>
<td>26 (8.5%)</td>
</tr>
<tr>
<td>Referral</td>
<td>16 (5.2%)</td>
<td>56 (18.2%)</td>
</tr>
<tr>
<td>Other</td>
<td>7 (2.3%)</td>
<td>9 (2.9%)</td>
</tr>
</tbody>
</table>

More than one option was chosen by several practitioners.
When a root filling was present and a small lesion (less than 1 cm wide) was visible on a radiograph, 62.5% of the respondents chose conventional root canal retreatment; 12.7% elected for apicectomy, 15.0% of cases would be referred. When a periapical lesion of more than 1 cm wide in combination with a root filling was present, the decisions of the respondents were ambiguous. Only 31.2% would perform root canal retreatment, 27.0% would carry out a root canal retreatment followed by an apicectomy. Referral in these cases was frequently chosen (24.8%) as well as apicectomy alone (17.3%) and extraction (15.0%). In these four situations, the older practitioners opted more often for referral.

Table 5-2-9 gives an overview of cases that respondents would consider for referral to an endodontist. Retrieval of silver points was the most popular reason for referral (56.7%), followed by surgical closure of perforations (47.6%) and surgical interventions (45.9%). Other referral cases in descending order were: post removal (39.4%), dens invaginatus (38.4%), trauma (37.1%), mutilated canal (36.2%), canal splitting in the apical third (34.9%), internal root resorption (33.9%), S-shaped (bayonet shaped) root canal (33.6%), calcified canal (33.2%), curved root canal (32.9%), missed canal (32.2%), external resorption (31.6%), root perforation (28.3%), large periapical lesion (25.1%), endodontic retreatment (15.6%), apexification procedure (15.3%), endodontic treatment of deciduous teeth (7.5%) and treatment of molar teeth (5.5%).

5.2.4. Discussion

Calcium hydroxide is recommended as the standard intracanal dressing in root canal treatment (Byström et al. 1985, Sjögren et al. 1991). In the present study, calcium hydroxide was used by 69.7% of the respondents, which is considerably more than the 21.1% in the study of Saunders et al. (1999), the 7% in the study of Jenkins et al. (2001) in the UK or the 9% in the USA (Whitten et al. 1996). In a Dutch study (Siers et al. 2001) the percentage of respondents using calcium hydroxide was 86.2%. These differences between countries are likely to be attributed to the different policies in dental training between universities (Qualtrough et al. 1999). Although there was no statistically significant difference between the different age groups in
Table 5-2-9: Endodontic cases considered for referral according to the number of respondents (n=307)

<table>
<thead>
<tr>
<th>Case to refer</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieval of silver point</td>
<td>174</td>
<td>56.7</td>
</tr>
<tr>
<td>Corrective surgery: closure of perforation</td>
<td>146</td>
<td>47.6</td>
</tr>
<tr>
<td>Surgical intervention</td>
<td>141</td>
<td>45.9</td>
</tr>
<tr>
<td>Post retrieval</td>
<td>121</td>
<td>39.4</td>
</tr>
<tr>
<td>Dens invaginatus</td>
<td>118</td>
<td>38.4</td>
</tr>
<tr>
<td>Trauma</td>
<td>114</td>
<td>37.1</td>
</tr>
<tr>
<td>Mutilated canal</td>
<td>111</td>
<td>36.2</td>
</tr>
<tr>
<td>Canal split in apical third</td>
<td>107</td>
<td>34.9</td>
</tr>
<tr>
<td>Internal resorption</td>
<td>104</td>
<td>33.9</td>
</tr>
<tr>
<td>S-shape (bayonet)</td>
<td>103</td>
<td>33.6</td>
</tr>
<tr>
<td>Calcified canal</td>
<td>102</td>
<td>33.2</td>
</tr>
<tr>
<td>Curved root canal</td>
<td>101</td>
<td>32.9</td>
</tr>
<tr>
<td>Missed canal</td>
<td>99</td>
<td>32.2</td>
</tr>
<tr>
<td>External resorption</td>
<td>97</td>
<td>31.6</td>
</tr>
<tr>
<td>Perforation</td>
<td>87</td>
<td>28.3</td>
</tr>
<tr>
<td>Large periapical lesion</td>
<td>77</td>
<td>25.1</td>
</tr>
<tr>
<td>Retreatment in general</td>
<td>48</td>
<td>15.6</td>
</tr>
<tr>
<td>Apexification procedure</td>
<td>47</td>
<td>15.3</td>
</tr>
<tr>
<td>Deciduous teeth</td>
<td>23</td>
<td>7.5</td>
</tr>
<tr>
<td>Molars in general</td>
<td>17</td>
<td>5.5</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>1.3</td>
</tr>
</tbody>
</table>

In this study, a similar trend, namely a decreased use of calcium hydroxide as a function of the period since graduation of the participants (Table 5-2-1) was observed as in some of the previous studies (Saunders et al. 1999, Jenkins et al. 2001). About one third of the practitioners did not use an interappointment medicament. Studies have shown that it is almost impossible to create a sterile root canal through cleaning and shaping of the root canal system and that regrowth of bacteria occurs in an empty root canal (Byström & Sundqvist 1981, Siqueira et al. 2002). Therefore, an intracanal dressing is advocated between appointments when a tooth is treated in more than one session.

Caustic and organic root canal disinfectants were used by 66.8% (Table 5-2-2), despite the well established use of calcium hydroxide. These products contain organic components such as paraformaldehyde, chlorophenol, parachloromono-
phenol, creosote, arsenicum anhydride, iodoform. It has been argued that most of these products should be prohibited since they are highly toxic, allergenic, mutagenic and carcinogenic and are harmful to patients (Lewis 1998). It has been shown that some of these products caused periodontal destruction and delayed healing of periapical tissues (Kopczyk et al. 1986, Yamasaki et al. 1994, Di Felice & Lombardi 1998), as they can escape from the root canal. In this respect, studies have documented their rapid and strong systemic distribution when used during endodontic treatment (Block et al. 1983, Fager & Messer 1986).

The sealing of access cavities between appointments is a determining factor in the inhibition of bacterial leakage and hence the prognosis of root canal treatment (Saunders & Saunders 1994). Cavit® is the product most favoured by Belgian practitioners (48.2%), with glass-ionomers being used by 31.3% of the respondents. Studies have shown that Cavit® adequately sealed access cavities of endodontically treated teeth (Beach et al. 1996), although a bacterial study (Barthel et al. 1999) reported that glass-ionomer was superior to Cavit®.

Cold lateral gutta percha condensation was the filling technique most frequently used (Table 5-2-4). Although it is common knowledge that single cone gutta percha fillings are not recommended (Beatty 1987), it was still used by 16.0% of the respondents. The results in Table 5-2-5 show that different types of warm gutta percha filling techniques were used by all ages. This clearly shows the effort made by a number of practitioners to use other filling techniques than those taught during dental graduate training.

This study also provided information on the endodontic decision making of the participants. On the one hand, retreatment of failed root fillings was the standard choice by the majority of the respondents (Table 5-2-8). On the other hand there was a clear trend towards more apicectomies and extractions with the increase of the size of the periapical lesion. The number of apicectomies and extractions even increased when the lesion was associated with root filled teeth. Studies have shown that the size of the periapical lesion is not a determining factor in healing (Sjögren et al. 1990). The presence of a root filling is also no reason for more radical treatments. Retreatment should always be the first option, although a number of complicating factors require surgery (Walton & Torabinejad 1996).
5.2.5. Conclusion

The use of calcium hydroxide was well established. Caustic products were used by some. The temporary seal of access cavities was in general provided by favoured materials. Most practitioners also used favoured filling techniques in combination with resin based sealers, although some relied on single cone (gutta percha or silver points) techniques. Retreatment in failed cases was not the first option for the majority of practitioners; surgery was preferred by most.
Chapter 6
Investigation of the effect of coronal restoration quality on the composition of the root canal microflora in teeth with apical periodontitis by means of T-RFLP-analysis

This chapter is accepted for publication:

ABSTRACT

Aim: To investigate the effect of the radiographic and clinical quality of coronal restorations on the composition of the root canal flora of both teeth with necrotic pulps and teeth with root canal fillings associated with apical periodontitis (AP).

Methodology: Twenty eight necrotic pulps and 35 root filled canals with signs of AP were studied. Both the coronal filling (presence of radiographically or clinically deficient margins and/or secondary caries) and the root filling (homogeneity and length) were scored. Bacterial root canal samples were taken with sterile paper points under rubber dam and using measures to prevent contamination. A DNA-based non-culture bacterial identification technique was used, namely terminal restriction fragment length polymorphism analysis (T-RFLP).

Results: Twelve samples were negative for bacterial DNA. A total of 33 different Terminal Restriction Fragment Lengths (TRFs) were detected. The Fusobacterium nucleatum/Streptococcus mitis group was the most frequently encountered TRF. The mean number of TRFs per necrotic pulp was 6.2 and 5.8 for the groups with acceptable and unacceptable coronal restorations respectively. This difference was not significant. In the root filled group, these values (respectively 5.2 and 8.6) were statistically significantly different (p<0.05). The following parameters in root filled teeth had no significant influence on the mean numbers of TRFs detected: the length and homogeneity of the root filling and the type of tooth (anterior – premolar – molar).

Conclusion: T-RFLP allowed the rapid assessment of bacterial biodiversity in root canal samples. The technique revealed the presence of bacteria that have rarely been described in the root canals with AP. Biodiversity in the root filled group was high, as compared to culture dependent studies where mono-infections were more frequently reported. Only in root filled teeth did teeth with defective coronal restorations have a statistically significant influence on the mean numbers of detected TRFs per sample.
6.1. Introduction

Coronal leakage has been recognized as a cause of failure in root canal treatment (Saunders & Saunders 1994). A number of in vitro studies have demonstrated the possibility of bacterial leakage along root fillings as well as along temporary coronal restorations (Khayat et al. 1993, Deveaux et al. 1999). These findings were supplemented by data from in vivo studies that indirectly described the effect of coronal leakage (Ray & Trope 1995, Tronstad et al. 2000, Chapter 4). These studies gave evidence of an increased incidence of apical periodontitis associated with defective root fillings and with leaking coronal restorations.

Bacteria are present in the oral cavity and potentially leak into root canals exposed to the oral environment. The analysis of these complex bacterial communities has classically been restricted to conventional culture methods. These methods are time-consuming and laborious. Furthermore, approximately 50% of the oral microflora cannot be cultured (Socransky et al. 1963). Others have shown that the serial dilution anaerobic culture procedure recovers only 20 to 70% of the microscopic count (Mombelli et al. 1989). Culture-independent molecular techniques, frequently based on the detection of 16S rRNA-genes, have been developed with the aim of covering also non-viable, uncultivable and fastidious bacteria. These techniques include fluorescent in situ hybridization (FISH) (Langendijk et al. 1995), denaturating gradient gel electrophoresis (DGGE) (Heuer & Smalla 1997), temperature gradient gel electrophoresis (TGGE) (Heuer & Smalla 1997), temporal temperature gradient gel electrophoresis (TTGE) (Vasquez et al. 2001) and cloning (Suau et al. 1999, Munson et al. 2002). This study used terminal restriction fragment length polymorphism analysis (T-RFLP) (Liu et al. 1997) to describe the microflora in root canals with necrotic pulps, as well as in root fillings associated with post-treatment disease. Thus far, only one study used T-RFLP for the characterization of the oral bacterial microflora in the saliva of healthy subjects and of patients with periodontitis (Sakamoto et al. 2003). Techniques such as T-RFLP may have the additional advantage of high throughput and reproducibility for monitoring bacterial communities (Osborn et al. 2000, Blackwood et al. 2003), thus providing a rapid method of finding major differences between communities and testing hypotheses based on a comparison of samples (Blackwood et al. 2003).
Culture based information is available on the composition of the bacterial microflora in necrotic root canals, as well as in failed root canals (Dahlen & Haapasalo 1998). In addition, molecular based techniques were also used to investigate the microflora of root canals with apical periodontitis (Conrads et al. 1997, Rolph et al. 2001, Munson et al. 2002, Siqueira et al. 2002). However, the effect of defective coronal restorations on a prospect shift in the composition of the root canal microflora in teeth with apical periodontitis has not yet been investigated.

The aim of the present study was therefore to investigate whether it was possible using T-RFLP to identify the effect of the radiographic and clinical quality of the coronal restorations on the composition of the root canal microflora of both teeth with necrotic pulps and teeth with root fillings associated with apical periodontitis.

6.2. Material & methods

6.2.1. Case selection

The 63 patients selected at random in this study all received conventional root canal treatment or retreatment. The patients were healthy adults (20 males and 43 females), with an average age of 40.3+/−14.0 years. This study was approved by the ethics committee of the Ghent University Hospital (N° 2003/006). Informed consent was obtained from all participants.

The samples were taken from previously untreated root canals with necrotic pulps (n=28) or filled root canals (retreatment cases) (n=35). All teeth included in the study had radiographic signs of apical periodontitis visible on a pre-treatment radiograph (i.e. at least twice the width of the normal periodontal ligament).

Data on coronal restorations were recorded. A coronal restoration was categorised as deficient when one of the following criteria was present: radiographic signs of deficient margins on the pre-treatment radiograph, clinical signs of a physical defect detected with a probe penetrating the tooth-restoration interface, secondary caries, partial or total loss of restoration. These parameters coincide with the criteria used in a previous study on coronal leakage (Chapter 4).

The following cases were excluded from the study:
- Teeth with a periodontal pocket extending to the apical third of the tooth.
- Teeth that could not be suitably isolated from the gingiva and saliva.
- Patients who received antibiotic treatment within the preceding 3 months.
- Patients with systemic disease.

The quality of an existing root filling was assessed on a pre-treatment radiograph according to length and homogeneity. The length was categorised as acceptable when the root filling terminated 0 to 2mm from the root apex. Over-extension and under-extension of the root filling was scored when the apical extent of the root filling ended respectively beyond the root apex and more than 2mm from the root apex. A root filling was scored homogenous when no voids were present and the root filling seemed well compacted in the root canal along the whole length of the root filling.

6.2.2. Sampling procedure

The teeth selected for bacterial sampling were first cleaned with pumice and a rubber dam was placed. Defective coronal fillings and caries, if present, were removed and the teeth and rubber dam were subsequently disinfected with 30% hydrogen peroxide and a 10% iodine tincture, according to the protocol proposed by Möller (1966). After the tincture had dried, the tooth surface was swabbed with a 5% sodium thiosulfate solution to inactivate the iodine tincture so that remnants of iodine would not influence the bacteriological sample.

Subsequently, canal access was gained and enlarged with Gates Glidden drills (Dentsply-Maillefer, Ballaigues, Switzerland). If present, the coronal part of the root filling was removed with Gates Glidden drills and the more apical part of the root filling was partially removed using K-flexofiles (Maillefer, Ballaigues, Switzerland). The instrumentation was carried out as close as possible to 2mm of the apical constriction. This was checked with an electronic apex locator (Apex Finder AFA, SybronEndo, Orange, USA). A small amount of saline (0.85%) was introduced in the canal with a sterile syringe. The fluid was then mixed with the contents of the root canal with a root canal file, making pumping movements. The canal fluid was subsequently soaked into a sterile paper point. The paper points were directly transferred to a tube containing sterile physiological water. The transport tubes were
transferred to the laboratory within 30 minutes. The root canal instrumentation was continued after the sampling procedure.

6.2.3. **DNA extraction**

For DNA extraction of bacteria that were collected on paper points, the QIAamp DNA mini kit (Qiagen, Hilden, Germany) was used according to the manufacturer's recommendations, with minor modifications. After 10 min centrifugation at 5000 × g, the pellet was resuspended in 180µL of lysis buffer (20mM Tris-HCl, pH 8.0; 2mM EDTA; 1.2% Triton). Fifty units of mutanolysin (25U/µL) (Sigma, Bornem, Belgium) were added and the samples were incubated for 30 min at 37°C. After the addition of 20µL Proteinase K (20mg/mL) and 200µL AL buffer (Qiagen), samples were incubated for 30 min at 56°C. Next, 200µL of ethanol was added and DNA was purified by adding the lysate to the Qiagen columns as described by the manufacturer. Finally, the total bacterial DNA was eluted with 100µL of AE buffer. DNA-extracts were stored at – 20°C.

6.2.4. **T-RFLP-analysis**

The forward primer 10f (5’ AGTGGATCCTGGCTCAG) and the reverse primer 534r (5’ ATTACCGCGGCTGCTGG) (Muyzer *et al.* 1993), which target the 16S rRNA gene (16S rDNA) of the domain *Bacteria*, were used to amplify part of the 16S rDNA by PCR. A 15µL PCR mixture contained 0.1µM of each primer, 7.5µL of Promega master mix (Promega, Madison, WI), 1.5µL of sample and distilled water. Thermal cycling consisted of an initial denaturation of 5 min at 94°C, followed by three cycles of 1 min at 94°C, 2 min at 50°C and 1 min at 72°C, followed by 35 cycles of 20 sec at 94°C, 1 min at 50°C and 1 min 72°C, with a final extension of 10 min at 72°C, and cooling to 10°C. A 20µL restriction mixture, containing 1µL PCR-product, 1µL of *BstU*I (Westburg, Leiden, The Netherlands) and 4µL of the appropriate buffer, was incubated at 60°C for 3 h. Ten microlitre of the restriction reaction was purified by ethanol precipitation. The obtained pellet was solved in 13.1µL deionised formamide (AMRESCO, Solon, Ohio, USA), 0.1µl ROX500 and 0.3µl HD400 GeneScan size standards (Applied Biosystems, Foster City, CA, USA) followed by denaturation at 96°C for 2 min and immediate cooling on ice. The fluorescently
labelled terminal restriction fragments (TRFs) were electrophoresed on an ABI PRISM 310 (Applied Biosystems). Figure 6-1 shows the output of a T-RFLP profile. TRFs with a peak height less than 10% of the highest peak were excluded from the analysis, since cloning studies (data not published) indicated that such peaks did not correspond with any of the species shown to be present by cloning.

![Figure 6-1: Terminal fragment length polymorphism analysis (T-RFLP) of a necrotic root canal with leakage](image)

The peaks are numbered according to the number of base pairs in the terminal fragment

6.2.5. Construction of the T-RFLP-library

The T-RFLP-pattern obtained from a mixed sample consists of the 5’ terminal BstUI restriction fragments obtained from amplified rDNA of the different species present. Theoretically the number of peaks (TRFs) reflects the number of different species present in a sample. Identification of the peaks in a T-RFLP pattern, in other words assignation of a species name to each TRF, is based on comparison with a library composed of the T-RFLP patterns of well-identified species. Such library T-RFLP patterns consist of a single TRF, since they are obtained from pure cultures of a single species. Another means to obtain T-RFLP-patterns of single species is by carrying out computer assisted (i.e. virtual) restriction analysis of published 16S rRNA sequences or by carrying out restriction analysis of cloned 16S rDNA, which is also sequenced to obtain the species name.
6.2.6. Data analysis

T-RFLP patterns were obtained as table files from the Genescan Analysis software and used in BaseHopper, a software program developed at our university (Baele et al. 2000). Using these sample files containing TRFs (peak values) in base pairs, this program enabled us to construct manually a library which contains one entry for each species and whereby each entry consists of a numeric value representing the peak value in base pairs. The peak values in the library entries are the averages of the peak values obtained after testing different strains or cloned 16S rRNA genes of each species.

Data analysis and statistical analysis were performed in SPSS 11.0.1 (SPSS Inc., Chicago, IL, USA). The mean number of TRFs per sample in the different groups were analysed with the Student t-test or ANOVA when more than 2 groups were present.

6.3. Results

A total of 12 samples, of which 9 in the root filled group, were PCR-negative. Of the 51 PCR-positive samples, 19 teeth showed signs of defective coronal restorations. Both the pulp necrosis group and the root filled group were divided into subgroups of teeth with acceptable and unacceptable coronal restorations. Table 6-1 gives an overview of the Terminal Restriction Fragments (TRFs) and the corresponding species or species groups present in the different patient subgroups. A total of 33 different TRFs were detected. The number of TRFs detected per sample ranged from 0-12 for the pulp necrosis group and 0-14 for the root filled group. Thirteen TRFs were present in all 4 groups. Among these, the TRF with a length of 25 bp (briefly TRF25), designated as the Atopobium-Treponema-group, TRF105 (Fusobacterium nucleatum/Streptococcus mitis group), TRF109-110 (an unidentified Veillonella sp.), TRF111 (Prevotella spp.), TRF 120 (the Cartonella/Peptostreptococcus/Eubacterium group) and TRF410 (the Campylobacter curvus/Dialister sp. group) were present in 19 or more of the patients. All 33 TRFs, except TRF452 (Prevotella heparinolytica), were present in the root filled group.
Table 6-1: Results of the T-RFLP-analysis in relation to the teeth subgroups (n=63)

<table>
<thead>
<tr>
<th>Species</th>
<th>T-RF length (bp)</th>
<th>No leakage</th>
<th>Leakage</th>
<th>No leakage</th>
<th>Leakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ato. parvulum / Cryptobacterium curtum / Olsenella genosp. C1 / Peptostreptococcus lacrimalis / Stacckia exigua / Treponema spp.</td>
<td>25 7 4 10 3 24</td>
<td>17 11 27 8 63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actinomyces sp. / Lactobacillus spp.</td>
<td>52-53 1 1 1 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capnocytophaga sp.</td>
<td>95 1 1 1 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capnocytophaga gingivalis / C. sputigena</td>
<td>99 1 1 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capnocytophaga ochracea</td>
<td>102 1 2 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fusobacterium nucleatum / Streptococcus mills group</td>
<td>105 7 6 14 3 30</td>
<td></td>
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</tr>
<tr>
<td>Veillonella sp.</td>
<td>109-110 11 4 10 3 28</td>
<td></td>
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<tr>
<td>Prevotella sp.</td>
<td>111 6 7 3 3 19</td>
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<tr>
<td>Prevotella sp.</td>
<td>114 4 4 2 10</td>
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</tr>
<tr>
<td>S. gordoni / Streptococcus mitis group</td>
<td>115 2 2 5 9</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Capnocytophaga sp.</td>
<td>95 1 1 2</td>
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<td>Capnocytophaga ochracea</td>
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<tr>
<td>Fusobacterium nucleatum / Streptococcus mills group</td>
<td>102 1 2 3</td>
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<tr>
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<tr>
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<td>S. gordoni / Streptococcus mitis group</td>
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<tr>
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<tr>
<td>Fusobacterium nucleatum / Streptococcus mills group</td>
<td>102 1 2 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veillonella sp.</td>
<td>109-110 11 4 10 3 28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevotella sp.</td>
<td>111 6 7 3 3 19</td>
<td></td>
<td></td>
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<tr>
<td>Prevotella sp.</td>
<td>114 4 4 2 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. gordoni / Streptococcus mitis group</td>
<td>115 2 2 5 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capnocytophaga sp.</td>
<td>95 1 1 2</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Capnocytophaga ochracea</td>
<td>99 1 2 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fusobacterium nucleatum / Streptococcus mills group</td>
<td>102 1 2 3</td>
<td></td>
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<tr>
<td>Veillonella sp.</td>
<td>109-110 11 4 10 3 28</td>
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<td>Prevotella sp.</td>
<td>111 6 7 3 3 19</td>
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<td>Prevotella sp.</td>
<td>114 4 4 2 10</td>
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<tr>
<td>S. gordoni / Streptococcus mitis group</td>
<td>115 2 2 5 9</td>
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<tr>
<td>Capnocytophaga sp.</td>
<td>95 1 1 2</td>
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<tr>
<td>Capnocytophaga ochracea</td>
<td>99 1 2 3</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Fusobacterium nucleatum / Streptococcus mills group</td>
<td>102 1 2 3</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Only 3 TRFs (TRF241 (the *Actinomyces israelii / Enterococcus faecalis* group), TRF245 (*Actinomyces* sp. / *Lactobacillus casei* group / *L. crispatus*) and TRF213 (unidentified isolate ED06B)) were not present in the necrosis group. TRF105 (representing the *Fusobacterium nucleatum/Streptococcus mitis* group) was the most frequently encountered TRF: (57.7% of the samples), followed by TRF109-110 (*Veillonella* sp.) in 28 samples (53.5%). TRF109-110 was the most frequent species (15 out of 25 samples) in the pulp necrosis group. In the root filled group, TRF105 (*Fusobacterium nucleatum / Streptococcus mitis* group) was counted 17 times (out of 27). The mean number of TRFs (i.e. species) per sample for the necrosis group was 6.21 and 5.82 for the sound coronal and defective coronal restoration group respectively. This difference was not statistically significant. In the root filling group, the mean number of TRFs was respectively 5.19 and 8.60. This difference was statistically significant (p<0.05).

Table 6-2 presents the number of TRFs in filled root canals according to the quality of the root filling and the tooth type. None of the parameters scored had a significant influence on the number of TRFs detected per sample.

Three TRFs (TRF200, 213 and 405) could be linked to a clone or an isolate, but 16S rRNA gene sequencing of both clone and isolate yielded unidentified organisms. Furthermore, 17 different TRFs, observed in a total number of 43 cases, could not be assigned to any organism. For example, TRF404 was observed in four samples, but no clone or organism could be associated with it.

6.4. Discussion

Dental periapical diseases are caused primarily by the spread of microorganisms and bacterial elements (toxins and endotoxins) from the root canal into the periapical area. Apical periodontitis is a polymicrobial infection dominated by obligatory anaerobic bacteria (Dáhlen & Haapasalo 1998). The number of different species per case is found to be relatively small, normally between two and eight, and particularly never more than 20 species in one root canal (Dahlén & Haapasalo 1998).
Table 6-2: The number of T-RFs in retreated teeth according to the quality of the root filling and the tooth type (n=26)

<table>
<thead>
<tr>
<th></th>
<th>T-RFs per sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td><strong>Length of the root filling</strong></td>
<td></td>
</tr>
<tr>
<td>Acceptable</td>
<td>7</td>
</tr>
<tr>
<td>Short</td>
<td>15</td>
</tr>
<tr>
<td>Overextended</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
</tr>
<tr>
<td><strong>Homogeneity of the root filling</strong></td>
<td></td>
</tr>
<tr>
<td>Homogeneous</td>
<td>7</td>
</tr>
<tr>
<td>Inhomogeneous</td>
<td>16</td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
</tr>
<tr>
<td><strong>Tooth type</strong></td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>6</td>
</tr>
<tr>
<td>Premolar</td>
<td>6</td>
</tr>
<tr>
<td>Molar</td>
<td>14</td>
</tr>
</tbody>
</table>

Negative samples were not included in this calculation

This study evaluated the usefulness of a molecular technique, namely terminal restriction fragment length polymorphism analysis (T-RFLP) for the study of dental periapical diseases.

The choice of the restriction enzyme used is important. *BstUI* was chosen, based on in silico-analysis of 16S rRNA genes and on the results of previous research (Engebretson & Moyer 2003), indicating that this restriction enzyme was well suited for maximal differentiation between bacterial species based on the length of the terminal 5’ restriction fragment of their 16S rDNA, i.e. their TRF. Nevertheless, several species turned out to have the same TRF. For example, after restriction with *BstUI*, the species *Atopobium parvulum*, *Cryptobacterium curtum*, *Olsenella genomospecies C1*, *Peptostreptococcus lacrimalis*, *Slackia exigua* and *Treponema* sp. were shown to have a TRF with a length of 25 bp. This means that the occurrence of this TRF in a T-RFLP-pattern does not allow differentiation between these different species.

A total of 33 different TRFs were detected in the present study. The number of TRFs per sample ranged from 0-12 in necrotic pulps and 0-14 in filled root canals. Although the average number of TRFs per canal that was detected in filled root
canals (5.63) was lower than that in necrotic pulps (6.04), this difference was not statistically significant. These results are in opposition to those studies using culture methods where it was shown that the microflora in filled root canals exists mostly as monoinfections (Molander et al. 1998, Sundqvist et al. 1998), probably due to the limitation of the culturing techniques and the higher sensitivity of DNA techniques. However, in cases with poor quality root fillings, the composition of the microflora found in culture-studies resembled that of untreated root canals. This difference is assumed to be a consequence of inadequate cleaning (Sundqvist et al. 1998, Cheung & Ho 2001). In this study no evidence of this assumption was seen, since the length and homogeneity of the root filling had no statistically significant influence on the number of TRFs detected in each sample.

Enterococci are found in approximately one third of the filled root canals with apical periodontitis (Möller 1966, Fraser 1974, Molander et al. 1998). E. faecalis appears to be extremely resistant to the antibacterial agents used during root canal treatment and it is one of the few micro-organisms that can survive the anti-bacterial effects of dressing with calcium hydroxide (Byström et al. 1985). Enterococci have also been shown to have the ability to survive in root canals as single organisms without the support of other bacteria (Fabricius et al. 1982). The TRF corresponding to E. faecalis or A. israelii (TRF241) was only present in the root filled group. Both bacteria were isolated, although the former more frequently, from filled root canals by other authors (Sundqvist et al. 1998, Molander et al. 1998, Hancock et al. 2001). On the other hand, Rolph et al. (2001), using molecular methods, failed to detect both. There is no obvious explanation for this difference in incidence of isolation of E. faecalis between the studies.

No information was available regarding the (possibly leaking) temporary fillings or the number of visits spent on the original root canal, which can also influence the presence of E. faecalis (Siren et al. 1997). The presence of defective coronal restorations did not seem to have effect on the presence of TRF241. In teeth with necrotic pulps, TRF 241 was absent. The incidence of TRF 241 was about the same for the samples taken from root filled teeth with unacceptable and acceptable coronal restorations (18.5% and 12.5% of the samples respectively).

No study has yet investigated the effect of the radiographic and clinical quality of the coronal restorations on the composition of the root canal microflora in teeth with necrotic pulps and teeth with post-treatment disease in vivo. No specific species
or group of species was found that indicated leakage. It was interesting to find that in root filled teeth with defective coronal restorations, the mean number of TRFs per sample detected was significantly higher than in other cases. Although care should be taken when interpreting this result because of different sample sizes, this difference in the mean number of TRFs per sample from teeth with unacceptable and acceptable coronal restorations could be explained by ingress of bacteria that increased the diversity of the microflora. Nevertheless, no similar significant difference could be detected in the samples from necrotic pulps.

Care should be taken when defining defective restorations (restorations that were scored radiographically and/or clinically unacceptable in this study) as restorations with coronal leakage. A minute gap at the coronal or radicular restoration interface, which would not be visible on the radiograph, could be sufficient to permit bacterial penetration.

Several explanations are possible for the fact that 12 samples produced negative results with the T-RFLP technique. Since the majority of these negative samples were found in the root filled group, it is not inconceivable that some of the cases were healing and that a restricted amount or no bacteria were present in the root canal. Apical radiolucencies are not necessarily caused by intracanal infection. A radiolucency may refer to a periapical cyst (Nair et al. 1996), a foreign body reaction (Nair et al. 1990, Sjögren et al. 1995) or scar tissue (Bhaskar 1966). It may also have been possible that errors in sampling resulted in negative samples. It was also possible that micro-organisms were present but that the sampling procedure did not pick-up the bacteria in some parts of the root canal. It should be noted that more negative samples were found with culture based methods (Molander et al. 1998: 32.0%, Cheung & Ho 2001: 33.3%, Sundqvist et al. 1998: 55.6%) than with the DNA technique used in the present study (19.0%) and in other studies (Conrads et al. 1997: 17.6%, Siqueira et al. 2002: 0%), although Rolph et al. (2001), who also used T-RFLP as well, reported 31.7% of the root canals to be negative.

This study is the first to use T-RFLP to investigate the composition of the root canal microflora. T-RFLP is most commonly used for systematic community analysis of environmental samples (Kitts 2001, Marsh 1999). The advantage of T-RFLP is a higher throughput and reproducibility in monitoring bacterial communities (Osborn et al. 2000, Blackwood et al. 2003). Also, T-RFLP was found to be very reproducible. A drawback of this technique however, is the sometimes limited discriminatory power,
since different species can present with the same TRF. Nevertheless, this approach allowed for the detection of bacterial species never previously found in endodontic infections by culture and was in agreement with the findings of other reports using molecular techniques (Conrads et al. 1997, Siqueira (2) et al. 2000, Jung et al. 2001, Rolph et al. 2001).

6.5. Conclusion

T-RFLP, a DNA-based non culture dependent approach made possible the rapid assessment of the bacterial biodiversity of necrotic pulps and filled root canals with apical periodontitis and revealed the presence of bacteria that have rarely been described in connection with this pathosis. Compared to other, culture-based studies, which usually indicate mono-infection of root filled canals associated with post-treatment disease, a higher diversity in these samples was found, probably due to the higher sensitivity of the technique used. No statistical differences with regard to biodiversity could be assessed between root canals with necrotic pulps and filled root canals. In root filled teeth, a significantly higher mean number of TRFs per sample was detected in samples with defective coronal restorations.

6.6. Acknowledgements

This study was partly funded by the ESE (European Society of Endodontology) research Grant 2001 and the FWO (Fonds voor Wetenschappelijk Onderzoek), grant nr. 1.5.126.04.
Chapter 7
General discussion and conclusion
7.1. General discussion

The complexity of the root canal and its ramifications is a challenge for the technical performance of endodontic treatment. Several methods and principles have been applied in pursuit of the goal of adequate cleaning and shaping the root canal system, and for the placement of a permanent filling to seal off the root canal from the oral environment. After treatment, the emergence or persistence of apical periodontitis is the criterion for long-term success or failure. While it is generally accepted that infection is a dominant cause of apical periodontitis and thus of a negative effect on treatment outcome in endodontics, technical and biological variables during treatment play both a direct and an indirect role in success and failure (Ørstavik et al. 2004).

At the end of the nineties, a survey of the most influential international scientific endodontic journals showed that during the last decade of the twentieth century, over 2000 reports were technical (including all kinds of testing instruments and equipment, n=934), experimental (including biological and microbiological laboratory-based testing, n=714) and clinical (covering all kinds of clinical studies, n=598) studies, while only 25 epidemiological studies could be found (Eriksen 1998). A dominance of mono-causal thinking prevailed focusing on details related to clinical endodontic activities, as was also stated by Eriksen et al. (2002).

The aim of this PhD thesis was therefore to provide additional epidemiological data (which were also lacking for the Belgian situation) and more information on potential factors that may influence the emergence or persistence of apical periodontitis in relation to root filled teeth.

Since apical periodontitis is a common disease associated with microbial infection of the root canal, this study was also aimed at analysing the root canal microflora of teeth with apical periodontitis and to correlate the composition of the endodontic microflora with the factors that might have influenced the emergence or persistence of apical periodontitis.

Four particular aims were put forward:

1. To investigate the prevalence of apical periodontitis and the relation between periapical health and the quality of root canal treatment in a Belgian population (Chapter 3).
2. To investigate the relationship between the quality of endodontic and restorative coronal treatment and the periapical status of root filled teeth, based on radiographic and clinical parameters (Chapter 4).

3. To gather information on the attitude and skills of dentists regarding endodontic treatment (this information has not yet been published in the scientific literature) (Chapter 5.1 and 5.2).

4. To examine whether it is possible to detect the influence of coronal restorations on the microbial composition in root canals on necrotic and failing root filled teeth using radiographic and clinical quality parameters (Chapter 6).

To fulfil the first aim (investigate the prevalence of apical periodontitis in a Belgian population), a group of patients that consulted the dental clinic of the Ghent University Hospital for the first time, in 1997 was radiographically evaluated for periapical health. This included root filled as well as non-root filled teeth. Patients that had already received dental treatment in the Ghent University dental clinic were barred from this study, in order to get a picture of general dental practice in Belgium and avoid interference of treatment performed under the supervised conditions of a university dental clinic.

It was noted that only 40.7% of the root fillings were scored as being of adequate quality, based on the length of the root filling. Although this figure was comparable to figures in other epidemiological studies across Europe and the USA (Table 1-1, Introduction), this result indicates that the quality of endodontic treatment performed on this Belgian population was disappointing. An explanation for the variance in the prevalence of apical periodontitis in the different studies is not obvious. Due to methodological variations among different studies (differences in population selection, diagnostic criteria and evaluation methods) it is difficult to compare percentages. However, the tendency is the same (Kirkevang & Hørsted-Bindslev 2002). The treatment profile and dental visiting habits are also different between the countries. Differences in dentist's skills and attitudes (e.g., extraction policy) and priorities among people also influence the treatment results of AP. Saunders et al. (1997) described differences in ages of the studied populations between the different studies.
This study revealed a clear link between the length of the root filling and the prevalence of apical periodontitis. The best results were obtained with root fillings ending 0 to 2mm from the radiological apex.

A distinct finding was that crowned teeth showed signs of periapical inflammation significantly more than teeth restored with plastic filling materials. A direct explanation, however, could not be provided on the basis of the data from this study.

The most striking finding was that the prevalence of apical periodontitis was ten times higher on root filled teeth than on non-root filled teeth (40.4% vs. 3.8%). It has been demonstrated previously (Kakehashi et al. 1965, Sundqvist 1976) that periapical inflammation is always caused by bacterial infection in the root canal. On root filled teeth, one can speculate on the cause of this root canal infection, but the obvious and well-known explanation is that most of these infections were avoidable if the treatment would have been carried out according to international guidelines. The high success percentage obtained in controlled clinical studies supports this statement (Table 1-2, Introduction, Eriksen 1998). It is therefore probable that the presence of apical periodontitis could have been avoided in the majority of the endodontic treatments studied here.

When detecting such high rates of apical periodontitis on root filled teeth, it is important to estimate the effect of healing of apical periodontitis on the prevalence. Petersson et al. (1991) showed that in long-term studies, the number of newly developing lesions is as high as the number of healed lesions. These investigators studied the same patients in 1974 and 1985 (n=351). Of the original 258 endodontically treated teeth, 82 showed radiographic signs of apical periodontitis. 11 years later, 18 of those were extracted, 15 retreated (of which 10 healed) and 49 were left untreated (19 healed and 27 did not heal). Of the 176 endodontically treated teeth without signs of apical periodontitis, 14 were extracted and 8 retreated. Of the 154 other root filled teeth, 22 new lesions developed. They concluded that the number of endodontically treated teeth with periapical lesions that healed during the 11-year observation period (19 teeth) was approximately the same as the number of endodontically treated teeth that developed an apical periodontitis (22 teeth). Ørstavik (1996) showed that apical periodontitis developed on roots of root filled teeth without pre-operative lesion and that the rate of these developing was approximately
the same as the rate of healing of lesions on root filled teeth. This further supports our interpretation of the data on apical periodontitis.

One of the questions that remained was the impact of the quality of the root fillings and the quality of the coronal restorations (coronal leakage) had on the periapical status. It would also have been interesting to know how endodontic treatment was carried out technically in Flanders. Worldwide information was also not available on this topic in the endodontic literature.

In chapter 4 of this study, the topic of coronal leakage was investigated. In chapter 3, we had already found the length of the root filling to be of influence on the prevalence of apical periodontitis. In this part, we investigated the effect of other parameters on the periapical health, particularly those possibly involved in coronal leakage.

This study was specifically designed to allow analysis of the data with logistic regression. Logistic regression has become the standard method of analysis in case of discrete outcome variables.

The information provided by periapical radiographs was used together with the results of the clinical evaluation of the coronal fillings. We found that 32.5% of the root filled teeth showed radiographic signs of apical periodontitis. This percentage was, although lower, comparable to the 40.4% from chapter 3. A possible explanation could be that the exclusive criteria from chapter 3 (no history of dental treatment in the University Hospital dental clinic) were not used in chapter 4. Therefore, endodontic treatment performed in our school were also included (we calculated that these teeth accounted for 23% of the total group). These endodontic treatments can have influenced the prevalence of apical periodontitis positively.

In this study, we found no significant difference in the prevalence of apical periodontitis between crowned teeth and filled teeth, in contrast to chapter 3. There was no obvious explanation for this difference.

The presence of a root canal post appeared to be of no statistically significant influence on the periapical health. Data on this topic were not available in chapter 3. Both the length and the homogeneity of the root filling were of significant influence on the periapical health. This was in accordance with the finding in chapter 3 on the effect of the length of the root filling. Overall, only 34% of the root fillings were scored acceptable on overall quality and 42% acceptable on length. It is, of course, not possible to get a 100% acceptable figure, due to the anatomical complexity of the
root canal system among other factors, but the figure in this study was low when compared to a number of clinical studies. In table 7-1, the adequate percentages in clinical studies are presented and compared with our study.

<table>
<thead>
<tr>
<th>Study</th>
<th>% Acceptable according to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>Hession 1981</td>
<td>88.7%</td>
</tr>
<tr>
<td>Nelson 1982</td>
<td>68.6%</td>
</tr>
<tr>
<td>Matsumoto et al. 1987</td>
<td>89.4%</td>
</tr>
<tr>
<td>Sjögren et al. 1990</td>
<td>69.7%</td>
</tr>
<tr>
<td>Smith et al. 1993</td>
<td>74.7%</td>
</tr>
<tr>
<td>Sjögren et al. 1997</td>
<td>68.3%</td>
</tr>
<tr>
<td>Heling et al. 2001</td>
<td>-</td>
</tr>
<tr>
<td>Iqbal et al. 2003</td>
<td>-</td>
</tr>
<tr>
<td>Dammaschke et al. 2003</td>
<td>81.0%</td>
</tr>
<tr>
<td>Cheung &amp; Chan 2003</td>
<td>78.3%</td>
</tr>
<tr>
<td>Farzaneh et al. 2004</td>
<td>74.8%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>79.3%</strong></td>
</tr>
<tr>
<td>Chapter 5</td>
<td><strong>42.0%</strong></td>
</tr>
</tbody>
</table>

Both the length of the root filling and the homogeneity of the root filling can, in this respect, be considered as indicators of the care that was taken in endodontic treatment. In this study, the quality of the coronal restoration and the root filling appeared to be of equal importance for the periapical health.

We were the first to investigate the effect of a base under a filling in relation to the prevalence of apical periodontitis. Saunders & Saunders (1994) suggested the importance of a base under a restoration to prevent coronal leakage, though clinical evidence was lacking. We found that the use of a base under a filling had a statistically significant positive effect on the periapical status.
The use of composite material significantly increased the presence of apical periodontitis as compared to amalgam fillings. This seemed to be in contradiction with the properties of composite materials. Composite fillings used with a bonding agent have the potential to bond to enamel and dentin and to create a tight seal. Nevertheless, composite materials are very operator sensitive and polymerization shrinkage with subsequent gap formation can occur, together with a variety of technical difficulties encountered during the clinical operation, which often produce a less than perfect result (Bergenholtz 2000). This can be an explanation for the increased presence of apical periodontitis on endodontically treated teeth coronally restored with composite.

There is no information in the literature on the possible effect on the periapical tissue of residual monomer in coronal restorations. Literature on the effect of composite on bone tissue is also scarce. Composite resin as a retrofil following apicectomy has shown to be successful (Rud et al. 1991, Jensen et al. 2002). Zhu et al. (2000) found favourable reactions of fibroblasts on MTA® (Mineral Trioxide Aggregate, Dentsply-Maillefer, Ballaigues, Switzerland) and composite resin as compared to IRM® (Dentsply De Trey, Konstanz, Germany) and amalgam. Maeda et al. (1999) found in a study on retrofilling materials in rats that the use of 4-meta-TBB resin Superbond® (Parkell, Farmingdale, USA) and light-cured composite resin resulted in the least inflammatory reaction, the largest amount of new bone formation and even regeneration of periodontal ligament. It seems therefore doubtful that residual monomer in coronal restoration is able to affect the periapical tissues.

According to the logistic regression model, the following factors in this study were predictive for the periapical status: the homogeneity and the length of the root filling and the radiographic appearance of the coronal restoration. For the teeth with coronal fillings, also the presence of a base was of significant influence.

In chapter 5, we used a questionnaire to gauge how endodontic treatment was performed in Flanders, Belgium. The questionnaire handled different topics in endodontic treatment concerning cleaning, shaping, filling and decision-making. One of the major findings was the limited use of rubber dam by the practitioners. Only 7% used it in all cases. Rubber dam is one of the most important factors in obtaining a sterile working environment. It is advised by all dental schools and endodontic societies as a condition sine qua non for endodontic treatment. Without the use of rubber dam, it is very hard to create a sterile root canal and this consequently affects
the success percentages negatively. This can be an obvious explanation for the high rate of apical periodontitis in relation to root filled teeth in Belgium.

The majority of practitioners performed most root canal treatments in two visits, even for single root canals. Although the number of visits showed no effect in treatment outcome in clinical studies, not using a rubber dam in combination with multiple visits increases the risk of unwanted contamination.

This study also showed a limited knowledge of root canal anatomy among the respondents, particularly concerning the second mesiobuccal canal in maxillary molars. We did not ask for all anatomical variations, but it is likely that a deviation in the number of root canals in other teeth is ignored (e.g., lower premolars and lower incisors).

Although sodium hypochlorite is the recommended standard for root canal irrigation during canal preparation, almost 20% of the respondents did not use it. This again can be a contributing factor for the inability to remove all bacteria from the root canal.

The use of reamers was still high among Flemish dentists. These instruments are no longer recommended for root canal treatment and should be abandoned in part because of their limited flexibility and limited dentin removal capacity (Tepel et al. 1995). The limited capabilities of reamers make them less efficient in treating curved root canals. This also accounts for H-files, which can be dangerous in treating curved canals because of their active tip and aggressive dentin removal capacity (Al-Omari et al. 1992). Flexible instruments, specifically Ni-Ti hand files were used by 49.5% of the respondents.

Although different preparation techniques were being used by the respondents, it remains very difficult to estimate their effect on treatment outcome, since no data on this topic are available.

Calcium hydroxide, the standard root canal interappointment dressing, was used by 70% of the respondents. Nevertheless, one third did not use any interappointment medication in the root canal. This is known to allow regrowth of bacteria in root canals, possibly contributing to an increase of endodontic failures.

Caustic and organic root canal disinfectants were still used by 67% of the respondents. Formaldehyde and formocresol have been shown to induce chronic tissue inflammation in the periapical area (Martin et al. 1968, Makkes et al. 1978). This can be a contributing factor to the genesis and/or preservation of apical
periodontitis after root canal treatment. No data on the effect of other caustic and organic products used in root canals are available.

The products used by the respondents for temporary access cavity closure were mostly Cavit® and glass-ionomer cement. Both are acceptable for this purpose, although one should bare in mind the limited strength of Cavit®, reducing its usefulness in extended cavities. If fracture or loss occurs, ingress of saliva and bacteria can again contribute to recolonization of the cleaned and shaped root canal.

The root canal filling techniques were mostly contemporary. As with the preparation technique, there is no evidence that the use of a particular technique implies higher clinical success rates. Moreover, it was demonstrated that about half of the practitioners felt that their preparation technique and filling technique could be improved. This was in agreement with the results in chapter 4 and 5 concerning the low quality of root fillings found.

This study showed that decisions made in case of treatment of apical periodontitis were not always the ones recommended (European Society of Endodontology 1994, American Association of Endodontists 1998). The size of the lesion influenced the decision making. Although studies have shown that the lesion-size cannot be a determining factor in the periapical healing process (Strindberg 1956, Weiger et al. 2000, Cheung & Chan 2003, Chugal et al. 2001, Ørstavik et al. 2004), the first choice is always conventional root canal (re-)treatment, taking into account that access to the canal can be made (European Society of Endodontology 1994, American Association of Endodontists 1998). The presence of a root filling in teeth with apical periodontitis also influenced the decision making process. Retreatment should still be the primary option in case of failing root fillings with periapical inflammation. These deviations in decision making from what is theoretically advised illustrated once again the limited confidence of the respondents in their proper endodontic abilities or the capabilities of endodontic treatment itself. This was also confirmed in discussions during the peer review sessions with the respondents.

In chapter 6, we aimed to study a possible effect of the radiographic and clinical quality of the coronal restorations on the composition of the root canal microflora in both necrotic canals as well as root filled teeth with apical periodontitis. A PCR-based DNA amplification technique, T-RFLP (terminal restriction fragment length polymorphism) was used. Leaking temporary restorations (coronal leakage)
have been mentioned as a possible factor in the presence of *E. faecalis*, but no other information appeared to be available on a possible effect of coronal leakage on the composition of the root canal microflora. In this study, we found no evidence of an increased presence of *E. faecalis* in samples with defective coronal restorations. We also found no evidence of specific species or of a specific group of species dominating root canals with defective coronal restorations.

An interesting finding was a significantly higher mean number of species in root filled teeth with defective coronal restorations as compared to root filled teeth with sealing coronal restorations. An explanation can be that the increased diversity of the canal microflora is a result of leakage. In case of root filled teeth without leakage, the microflora can be explained by bacteria that could not be removed from the root canal by the practitioner and by the presence of therapy resistant bacteria. Furthermore, studies have shown a limited microflora that is implicated in endodontic failures (Molander *et al.* 1998), which could possibly correspond to the group of failing root fillings without signs of coronal leakage. A similar finding of the effect of coronal leakage in necrotic root canals could not be found.

### 7.2. Conclusion

The percentage of apical periodontitis associated with endodontic treatment was disappointingly high. This finding was associated with a high number of root fillings that were scored unacceptable on radiographs.

It has been reported that one of the causes of the poor quality of endodontic treatment performed in general practice may be that students graduate with a lack of expertise and a poor understanding of the principles involved (Dummer 1991). It is therefore of the utmost importance that efforts are made to optimize endodontic treatment of vital as well as necrotic teeth, included teeth with apical periodontitis. Endodontic treatment strategies should be outlined, to improve future under- and postgraduate education in endodontology.

We found that a well-sealing coronal restoration and a well-performed root canal treatment were both important for the overall success of root canal treatment. Data suggested that the problem of coronal leakage may not be of such clinical
impact as indicated by previous studies, provided endodontic treatment procedures are carefully carried out. Nevertheless, along with emphasis on the technical aspects of root canal treatment, dentists should be aware of the importance of maintaining a tight coronal seal and to replace defective restorations before bacteria are able to enter the root canal space. A way to increase the certainty of the coronal seal is to place a base under a restoration.

It is clear that a large percentage of dentists, irrespective of the time since their graduation, rely on techniques and use products and materials which are currently favoured by expert opinion. Nonetheless, half of the respondents in the study seemed not to be satisfied with their preparation and filling technique, which complied with the poor results noted in chapter 3 and 4 concerning the quality of the root fillings.

The use of calcium hydroxide is well established, although one third did not use any interappointment dressing. Caustic products are still used, despite evidence of their toxicity. The temporary seal of access cavities is in general provided by favoured materials. Most practitioners also use favoured filling techniques in combination with resin-based sealers, although some rely on single cone (gutta percha or silver points) techniques. Decision making by the respondents in case of necrotic and root filled teeth with apical periodontitis deviated from what is theoretically correct.

T-RFLP, a DNA-based non-culture dependent approach made possible the rapid assessment of the bacterial biodiversity of necrotic and filled root canals with apical periodontitis and revealed the presence of bacteria that have rarely been described in connection with this pathology. Compared to other, culture-based studies, which usually point to mono-infection of retreated root canals, we found a higher diversity in these samples. No statistical differences with regard to biodiversity could be assessed between necrotic root canals and filled root canals. In root filled teeth, a significantly higher number of species was detected in samples with defective coronal restorations, indicating an increasing effect of coronal leakage on the biodiversity of the root canal microflora. More research is needed to investigate the effect of this difference on the emergence or persistence of apical periodontitis in root filled teeth.
Chapter 8
Summary - Samenvatting
8.1. Summary

Apical periodontitis is an inflammatory lesion mainly situated around the root tip and is caused primarily by bacteria and their toxic by-products that leak out of the root canal into the surrounding tissues.

Epidemiological research on the prevalence of apical periodontitis was limited at the start of this thesis. Figures on the prevalence of apical periodontitis in a Belgian population were non-existent.

It has already been demonstrated that apical periodontitis is frequently associated with root filled teeth. This indicates that the quality of endodontic treatment and the attitude of the dentists towards endodontic treatment are influential on the prevalence of apical periodontitis.

The quality of the coronal restoration also influences the prevalence of apical periodontitis, along with the quality of the endodontic treatment. Research on this topic was limited to the radiographic evaluation of the coronal and endodontic parameters of quality and the existence of apical lesions. The clinical evaluation of the quality of the coronal restorations as related to failing root fillings has not yet been investigated.

Questions remain regarding whether the composition of the root canal flora in the presence of an apical inflammatory lesion is influenced by deficient coronal restorations.

The following aims were propounded for this thesis on the basis of these remaining questions:

1. To investigate the prevalence of apical periodontitis and the relation between periapical health and the quality of root canal treatment in a Belgian population (Chapter 3).
2. To investigate the relationship between the quality of endodontic and restorative coronal treatment and the periapical status of root filled teeth, on both a radiographic and on clinical parameters basis (Chapter 4).
3. To gather information on the attitude and skills of dentists regarding endodontic treatment (this information had not yet been published in the scientific literature)(Chapter 5.1 and 5.2).

4. To examine whether it was possible to detect the influence of coronal leakage on the microbial composition in root canals of necrotic and failing root filled teeth (Chapter 6).

In chapter 3, it was found that in a Belgian population, 6.6% of all examined teeth showed radiographic signs of apical periodontitis; this was 3.8% on non-root filled teeth and 40.4% on root filled teeth. Of this patient group, 63.1% had at least one tooth with apical periodontitis. The prevalence of apical periodontitis was influenced by the quality of the root filling. The best result was seen on root fillings ending 0 to 2mm from the radiographic apex (25.2% apical periodontitis). Root fillings ending more than 2mm short of the radiographic apex (52.1% apical periodontitis) and overextended root fillings (75.0% apical periodontitis) scored significantly worse.

Chapter 4 studied the effect of the coronal restoration and the root filling on the periapical condition (prevalence of apical periodontitis). The quality of the coronal restoration of 745 root filled teeth was scored radiographically as well as clinically. The quality of the root filling was scored radiographically. Only 34.4% of the root fillings were scored acceptable, according to the criteria proposed by the ESE (European Society for Endodontology) and the AAE (American Association of Endodontists). It was found that the length as well as the homogeneity of the root filling was of significant influence on the prevalence of apical periodontitis. Of the coronal restorations, 78.1% were scored acceptable. The quality of the coronal restoration as well as the obturation material was associated with significant differences in the prevalence of apical periodontitis (more apical lesions following restoration with composite). The presence of a base under a restoration was found to significantly decrease the prevalence of apical periodontitis. When analysing the data with logistic regression analysis, the following parameters were predictors for the periapical status: the homogeneity and length of the root filling, the radiographic appearance of the coronal restoration and the presence of a base under the coronal restorations.
Chapter 5 aimed at gathering information through a questionnaire on the nature of root canal treatment carried out by Flemish dentists and on possible factors influencing the quality of endodontic treatment performed. Specific information regarding root canal cleaning, shaping and filling, endodontic knowledge and endodontic treatment decision in relation to periapical pathology was gathered.

Of the respondents, only 7% used rubber dam (sterile working environment) in all cases.

A clear trend was observed towards an increased number of treatment visits when more root canals were to be treated. 82.4% of the respondents used NaOCl as a root canal irrigant and 61.4% used EDTA (both favoured for root canal cleaning purposes and removal of the smear layer).

K-files were still popular (60.3%) along with reamers (55.4%) and H-files (46.9%). Flexible Ni-Ti hand files were used by half of the respondents, engine driven rotary instruments were used by 27.7% of the respondents. The most frequently used canal preparation techniques were stepback, stepdown combined with stepback, stepdown and reaming. Half of the respondents felt their preparation technique could be improved.

Approximately one third of the group did not use any intracanal dressing between endodontic appointments, 69.7% used Ca(OH)$_2$. A striking finding was that 66.8% still used caustic products. Glass-ionomers and Cavit® were most frequently used as temporary restoration material.

Cold lateral condensation was the most popular root canal filling technique (65.8%). Some filling techniques that are no longer favoured such as placement of silver points/cones were still used, although more by the older practitioners. Half of the practitioners felt their obturations could be performed better.

This study showed that decisions made in case of treatment of apical periodontitis were not always the ones recommended (ESE — AAE). The size of the apical lesion as well as the canal status influenced decision-making.

Chapter 6 investigated the effect of coronal restoration quality on the composition of root canal microflora. A new PCR-based DNA amplification technique, T-RFLP (terminal restriction fragment length polymorphism) was used. Necrotic and root filled teeth with radiographic signs of apical periodontitis were analysed. No evidence was found of an increased presence of *E. faecalis* in teeth with defective
coronal restorations, nor was evidence found of specific species or of a specific group of species dominating root canals with defective coronal restorations (*E. faecalis* is often mentioned in the literature as a cause of endodontic failures). A significant higher mean number of species in root filled teeth with defective coronal restorations as compared to root filled teeth with sealing coronal restorations was found.
8.1. Samenvatting

Apicale parodontitis is een ontstekingsletsel voornamelijk gesitueerd rondom de tip van de tandwortel en wordt hoofdzakelijk veroorzaakt door bacteriën en hun toxische bijproducten die uit het wortelkanaal in de omringende weefsels lekken.

Epidemiologisch onderzoek naar de prevalentie van apicale parodontitis was bij de start van deze thesis eerder beperkt. Cijfergegevens betreffende de prevalentie van apicale parodontitis in een Belgische populatie waren onbestaande.

Men heeft aangetoond dat apicale parodontitis vaak met reeds endodontisch behandelde tanden geassocieerd is. Dit wijst erop dat kwaliteit van endodontische behandelingen en de manier waarop tandartsen tegenover endodontische behandelingen staan een invloed heeft op het voorkomen van apicale parodontitis.

Naast endodontische kwaliteit blijkt ook de kwaliteit van het coronale herstel een invloed te hebben op de prevalentie van apicale parodontitis. Onderzoek heeft zich enkel toegespitst op de radiografische evaluatie van de coronale en de endodontische kwaliteitsparameters en het optreden van apicale haarden. De klinische evaluatie van de kwaliteit van het coronale herstel in relatie tot de falende endodontische behandeling werd nog niet onderzocht.

In dit verband kan men zich ook de vraag stellen of de samenstelling van de wortelkanaalflora bij casi met een apicale haard beinvloedt wordt door coronaal deficiënte restauraties.

Op basis van deze nog openstaande vragen werden de volgende doelstellingen vooropgesteld bij deze thesis:

1. Het vastleggen van de prevalentie van apicale parodontitis en de relatie tussen de periapicale gezondheid en de kwaliteit van wortelkanaalbehandeling in een Belgische populatie (Hoofdstuk 3).
2. Het onderzoeken van het verband tussen de kwaliteit van wortelkanaalbehandelingen en coronale restauraties, en de periapicale gezondheid van endodontisch behandelde tanden, niet alleen op een radiografische basis, maar ook gebaseerd op klinische parameters (Hoofdstuk 4).
3. Het verzamelen van informatie betreffende de houding en de vaardigheden van tandartsen betreffende endodontische behandelingen (deze informatie was nog niet gepubliceerd in de wetenschappelijke literatuur) (Hoofdstuk 5.1 en 5.2).

4. Onderzoeken of het mogelijk was om de invloed van coronale lekkage op de microbiële samenstelling in wortelkanalen in necrotische en falende endodontisch behandelde tanden te detecteren (Hoofdstuk 6).

In hoofdstuk 3 werd beschreven dat 6,6% van alle onderzochte tanden in een Belgische populatie radiografische tekenen van apicale parodontitis vertoonden; dit was 3,8% bij niet-endodontisch behandelde tanden en 40,4% bij endodontisch behandelde tanden. Van deze patiëntengroep had 63,1% minstens één tand met apicale parodontitis. Tanden gevuld met plastische vulmaterialen vertoonden meer apicale parodontitis dan gekroonde tanden. De prevalentie van apicale parodontitis werd beïnvloed door de kwaliteit van de wortelkanaalvullingen. Het beste resultaat werd gezien bij wortelkanaalvullingen eindigend 0 tot 2mm van de radiografische worteltop (25,2% apicale parodontitis). Wortelkanaalvullingen eindigend meer dan 2mm korter dan de radiografische worteltop (52,1% apicale parodontitis) en overextensie van wortelkanaalvullingen scoorden beduidend slechter (75,0% apicale parodontitis).

Hoofdstuk 4 bestudeerde het effect van de kroonrestauratie en de wortelkanaalvulling op de periapicale gezondheid (prevalentie van apicale parodontitis). De kwaliteit van het coronale herstel van 745 endodontisch behandelde tanden werd zowel klinisch als radiografisch gescoord. De kwaliteit van de wortelkanaalvulling werd radiografisch gescoord. Slechts 34,4% van de wortelvullingen werden conform de vooropgestelde criteria van aanvaardbare kwaliteit volgens de ESE (European Society for Endodontology) en de AAE (American Association of Endodontists) gescoord. Zowel de lengte als de homogeniteit van wortelkanaalvulling hadden een significante invloed op het voorkomen van apicale parodontitis. Van de kroonrestauraties werden 78,1% als ‘aanvaardbaar’ gescoord. De kwaliteit van de kroonrestauratie evenals het type vulmateriaal waren geassocieerd met significante verschillen in het voorkomen van apicale parodontitis (meer apicale laesies na herstel met composiet). De
aanwezigheid van een onderlaag (base) onder een restauratie resulteerde in beduidend minder apicale parodontitis. Na analyse van de gegevens met logistische regressieanalyse waren de volgende parameters decisief voor de periapicale status: de homogeniteit en de lengte van de wortelkanaalvulling, de radiografisch gescoorde kwaliteit van de kroonrestauratie en de aanwezigheid van een onderlaag onder coronale vullingen.

Hoofdstuk 5 beoogde het verzamelen van informatie met een vragenlijst betreffende de aard van de endodontische behandelingen uitgevoerd door Vlaamse tandartsen en de mogelijke factoren die de kwaliteit van de uitgevoerde endodontische behandelingen beïnvloeden. Specifieke informatie werd vergaard betreffende het reinigen, vormgeven en vullen van het wortelkanaal, de endodontische kennis en de endodontische behandelingsskeuzes met betrekking tot periapicale pathologie. Van de ondervraagden gebruikte slechts 7% rubberdam (steriele werkomgeving) in alle gevallen. Een duidelijke tendens naar een verhoogd aantal zittijden bij de behandeling van meerdere wortelkanalen werd waargenomen. 82,4% van de ondervraagden gebruikte NaOCl als wortelkanaalspoelmiddel en 61,4% gebruikte EDTA (beiden worden geadviseerd voor het reinigen van wortelkanalen en verwijderen van de smeerlaag). K-vijlen waren vrij populair (60,3%), naast ruimers (55,4%) en H-vijlen (46,9%). Flexibele NiTi-handvijlen werden door de helft van de ondervraagden gebruikt, roterende wortelkanaalinstrumenten werden gebruikt door 27,7% van de ondervraagden. De meest gebruikte wortelkanaalpreparatietechnieken waren: stepback, stepdown gecombineerd met stepback, stepdown en ruimen. De helft van de ondervraagden vond dat de eigen preparatietechniek vatbaar was voor verbetering.

Ongeveer één derde van de ondervraagde groep gebruikte geen intra-canalaire antiseptica tussen de endodontische behandelzittijden; 69,7% gebruikte Ca(OH)₂. Een opmerkelijke vondst was dat 66,8% nog steeds caustische producten gebruikte. Glas-ionomeer en Cavit® werden het vaakst gebruikt als tijdelijk restauratief materiaal.

Laterale koude gutta-percha condensatie was de populairste vultechniek (65,8%). Sommige verlaten vultechnieken, zoals het plaatsen van zilverstiften/-punten, werden nog gebruikt; dit bleek meer het geval te zijn bij oudere practici. De
helft van de practici vond dat de eigen wortelkanaalvullingen beter konden worden uitgevoerd.

Deze studie toonde verder nog aan dat de behandelopties die in het geval van behandeling van apicale parodontitis worden genomen niet steeds conform de geadviseerde strategie (ESE – AAE) waren. De grootte van het apicale letsel evenals de kanaalstatus beïnvloedde de besluitvorming van de ondervraagden.

**Hoofdstuk 6** onderzocht het effect van de kwaliteit van de coronale restauratie op de samenstelling van de microflora in het wortelkanaal. Een nieuwe PCR-gebaseerde DNA-amplificatietechniek, T-RFLP (terminal restriction fragment length polymorphism) werd gebruikt. Necrotische en endodontisch behandelde tanden met radiografische symptomen van apicale parodontitis werden geanalyseerd. Er werd geen bewijs gevonden van een verhoogde aanwezigheid van *E. faecalis* in tanden met gebrekkige kroonrestauraties (*E. Faecalis* is het micro-organisme dat het meest wordt vermeld in de literatuur betreffende falende wortelkanaalvullingen). Noch werd bewijs gevonden van overheersing door specifieke species of door een specifieke groep species van de flora in wortelkanalen in associatie met gebrekkige kroonrestauraties. Een significant hoger gemiddeld aantal soorten per kanaal werd wel gevonden in endodontisch behandelde tanden met gebrekkige kroonrestauraties in vergelijking tot endodontisch behandelde tanden met goed afsluitende coronale restauraties.


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Supplement
VRAGENLIJST ENDODONTOLOGIE

I. PERSOONLIJKE GEGEVENS

1. U bent afgestudeerd aan
   - KUL
   - RUG
   - VUB
   - UCL
   - ULB
   - Andere

2. Aantal jaar praktijkervaring
   - 0-5 j
   - 6-10 j
   - 11-15 j
   - 16-20 j
   - 20-25 j
   - > 25 j

3. Man
   - Vrouw

4. Deeltijds
   - Voltijds

5. Uw praktijk is gelegen in een gemeente met
   - 0-2500 inw.
   - 2.5-10.000 inw.
   - 10.-25.000 inw.
   - 25.-50.000 inw.
   - 50.-100.000 inw.
   - >100.000 inw.

6. De klemtoon bij Uw praktijkvoering ligt bij
   - Omnipracticus
   - Endodontie
   - Esthetiek
   - Orthodontie
   - Parodontologie
   - Pedodontie
   - Prothese
   - Andere

II. DE ENDODONTISCHE BEHANDELING

1. Tandisolatie - U gebruikt de rubberdam
   - zelden
   - soms
   - altijd
   - voor U specifieke indicatie

2. Hoeveel endodontische behandelingen voert U gemiddeld per week uit?
   - 0
   - 1
   - 2
   - 3
   - 4
   - 5
   - 5-10
   - 10-15
   - 15-20
   - 20-25
   - > 25
3. Hoeveel zittijden besteedt U aan de preparatie en vulling van 1 wortelkanaal?
1 zittijd  2 zittijden  3 zittijden  >3 zittijden
☐  ☐  ☐  ☐

4. Hoeveel zittijden besteedt U aan de preparatie en vulling van 2 wortelkanalen?
1 zittijd  2 zittijden  3 zittijden  >3 zittijden
☐  ☐  ☐  ☐

5. Hoeveel zittijden besteedt U aan de preparatie en vulling van 3 wortelkanalen?
1 zittijd  2 zittijden  3 zittijden  >3 zittijden
☐  ☐  ☐  ☐

6. Hoeveel zittijden besteedt U aan de preparatie en vulling van 4 wortelkanalen?
1 zittijd  2 zittijden  3 zittijden  >3 zittijden
☐  ☐  ☐  ☐

7. Hoe vaak prepareert U en vult U een vierde kanaal in de 16 en 26?
0%  1%  2-5%  6-10%  11-20%  21-25%  26-50%  51-75%  76-100%
☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐

8. Hoe vaak prepareert U en vult U een vierde kanaal in de 17 en 27?
0%  1%  2-5%  6-10%  11-20%  21-25%  26-50%  51-75%  76-100%
☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐

9. Hoe vaak heeft U al een C-vormig kanaal geprepareerd en gevuld in een ondermolaar?
0%  1%  2-5%  6-10%  11-20%  21-25%  26-50%  51-75%  76-100%
☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐

10. Welk irrigans gebruikt U bij de kanaalpreparatie?
Chlooramine  Chloorhexidine  Natriumhypochloriet  Water  Waterstofperoxyde
☐  ☐  ☐  ☐  ☐
Fysiologische zoutoplossing  Andere
☐  ☐

11. Indien U Natriumhypochloriet gebruikt, wat is de concentratie?
0,5%  1%  1,5%  2%  2,5%  5%  Andere  Onbekend
☐  ☐  ☐  ☐  ☐  ☐  ☐  ☐
12. Welk vulmateriaal gebruikt U als voorlopige coronaire restauratie?
ZOE IRM Cavit/Ciprosad Glasionomeer Composiet Amalgaam Andere
☐ ☐ ☐ ☐ ☐ ☐ ☐

13. Welk vulmateriaal gebruikt U als tussentijdse kanaalvulling?
Calciumhydroxide Geen Andere
☐ ☐ ....................

14. Welke werklengte beoogt U ten opzichte van de radiografische apex?
Tot aan de radiografische apex U perforeert steeds licht 0,5 mm 1 mm 1,5 mm
☐ ☐ ☐ ☐ ☐ ☐
2 mm 2,5 mm 3 mm >3 mm tactiele stop
☐ ☐ ☐ ☐ ☐

15. Maakt U gebruik van de elektrische lengtebepaling?
Soms Zelden Nooit
☐ ☐ ☐

Welk toestel gebruikt U: ........................................

16. Hoe behandelt U een nog niet endodontisch behandelde tand met een kleine peri-apicale opklaring?
i.e. < 1 cm?
Extractie Endo+Apexresectie Endo Apexresectie Doorverwijzing Geen Andere
☐ ☐ ☐ ☐ ☐ ☐ ☐

17. Hoe behandelt U een nog niet endodontisch behandelde tand met een grote peri-apicale opklaring?
i.e. > 1 cm?
Extractie Endo+Apexresectie Endo Apexresectie Doorverwijzing Geen Andere
☐ ☐ ☐ ☐ ☐ ☐ ☐

18. Hoe behandelt U een endodontisch behandelde tand met een kleine peri-apicale opklaring?
i.e. < 1 cm?
Extractie Endo+Apexresectie Endo Apexresectie Doorverwijzing Geen Andere
☐ ☐ ☐ ☐ ☐ ☐ ☐
19. Hoe behandelt U een endodontisch behandelde tand met een grote peri-apicale opklaring?
i.e. > 1 cm?

Extractie  Endo+Apexresectie  Endo  Apexresectie  Doorverwijzing  Geen  Andere

20. Hoe staat U tov. endodontologie als tweedelijnsverzorging?
Scoor op een schaal van 0 tot 10:............................

21. Welke van de volgende endobehandelingen vindt U tweedelijnsverzorging?

- endodontische behandeling van molaren
- opzoeken van een gemist kanaal
- endodontische herbehandeling (algemeen)
- endodontische herbehandeling : verwijderen van wortelstiften
- endodontische herbehandeling : verwijderen van zilverpunten
- endodontische herbehandeling : verwijderen van afgebroken instrumenten
- endodontische herbehandeling van een gemutileerd kanaal (ledging, zipping, stripping)
- gecalcificeerd wortelkanaalsysteem
- perforaties van wortel of de pulpabodem
- zeer grote apicale laesie
- wortelresorpties externe
- wortelresorpties interne
- anatomische complicaties : dens invaginatus
- anatomische complicaties : wortelkanaalsplitsing in apicale derde
- anatomische complicaties : sterke wortelkromming (50° of meer)
- anatomische complicaties : S-vormige wortelkanaalanatomie (bajonet)
- apexificatie
- traumatologie met wortelbreuken
- chirurgische endodontologie (behandeling v/e apicale opklaring)
- correctieve chirurgie : sluiten van perforaties
- endo in het melkgebit
- andere : .................................................................
III. INSTRUMENTARIJUM EN DE KANAALPREPARATIE

1. Welke instrumenten gebruikt U standaard?
Reamer   Vijl   Hedströmvijl   Reamer+Vijl   Reamer+Hedström   Vijl+Hedström
☐   ☐   ☐   ☐   ☐   ☐
Reamer+Vijl+Hedström
☐

2. Welke preparatietechniek past U toe?
Ruimtechniek   Step-back techniek   Step-down   Combinatie Step-down/step-back
☐   ☐   ☐   ☐
Andere
.....................

3. Zijn volgende technieken u bekend?
   Crown-down Ja ☐   Neen ☐
   Modified double flared techniek Ja ☐   Neen ☐
   Crown-down pressureless techniek Ja ☐   Neen ☐
   Balanced force / Roane techniek Ja ☐   Neen ☐

4. Gebruikt u Nikkeltitaniumvijlen? Ja ☐   Neen ☐

5. Maakt U gebruik van chelaten?
   EDTA(vloeibaar) File-Eze RC-prep Andere
☐   ☐   ☐   ☐
.............................

6. Bent U tevreden over Uw huidige preparatietechniek?
   Ja ☐   Kan beter ☐   Neen ☐

7. Doet U ook machinale kanaalpreparatie? Ja ☐   Neen ☐

Welk instrument gebruikt U voor de machinale kanaalpreparatie?
...........................................................................................................................................
8. Zijn de volgende namen U bekend?

- Files of greater taper: Ja □ Neen □
- Profile: Ja □ Neen □
- Light Speed: Ja □ Neen □
- Quantec: Ja □ Neen □
- Safety Hedströms: Ja □ Neen □
- Piezomatic: Ja □ Neen □

9. Doet U ook herbehandelingen? Ja □ Neen □

10. Gebruikt u hierbij bepaalde solventia?

- Chloroform □
- Terpentijn □
- Endosolv E □
- Endosolv R □
- Largal □
- Geen □
- Andere □

IV. KANAALVULLING

1. Welke vultechniek past U toe?

- Enkel pasta □
- Zilverstift □
- Gutta Single Cone □
- Koude Laterale Condensatie □
- Warme Laterale Condensatie □
- Vertikale Condensatie □
- Compactoren □
- Thermafil □
- Softcore □
- Andere □

2. Welke pasta of sealer gebruikt U?

- Endomethasone □
- ZOE □
- AH26 □
- AH+ □
- Topseal □
- Sealapex □
- Tubliseal □
- Ketac-Endo □
- Grossmann □
- N2 Sargenti □
- Andere □

3. Bent U tevreden over Uw obturatietechniek?

- Ja □
- Kan beter □
- Neen □

4. Gebruikt U caustische produkten in het wortelkanaal?

- Caustinerf arsenic □
- Caustinerf non-arsenic □
- Pulperyl □
- Toxavit □
- Rockle's □
- CHKM □
- Crésophène □
- Septomixine □
- Tempophore □
- Andere □