MARGARETHA KOCH

ON IMPLEMENTATION OF AN ENDODONTIC PROGRAM

Change of practice, treatment outcome and cost-effectiveness
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"Om ett viss socialt fenomen, F, kan man ställa sig en lång rad olika frågor, till exempel dessa: Förekommer F överallt eller endast på somliga platser? […] Är F förknippad med den här kategorin av folk snarare än med den där kategorin av folk? […] Vad är orsaken till F?

Sedan kan man också fråga sig: Vad betyder F?"

“About a certain societal Phenomenon, P, one could ask oneself a number of diverse questions, such as: Is P present everywhere or just in certain places? […] Is P typical for just this category of people, rather than for that category? […] What causes P?

Then of course you could ask yourself: What does P mean?”

Johan Asplund
Ur Om undran inför samhället (1970)
ABSTRACT

It is widely accepted that the uptake of research findings by practitioners is unpredictable, yet until they are adopted, advances in technology and clinical research cannot improve health outcomes in patients. Despite extensive research there is limited knowledge of the processes by which changes occur and ways of measuring the effectiveness of change of practice. The overall aim of this thesis was to investigate aspects of an educational intervention in clinical endodontic routines and new instrumentation techniques in a Swedish County Public Dental Service. Special reference was made to the establishment of changed behaviour in practice, the process of change, and the clinical effects.

Although a high level of competence in root canal treatment procedures is required in general dental practice, a number of Swedish studies have revealed inadequate root-fillings quality and associated periapical inflammation in general populations. It is suggested that the adoption of the nickel-titanium rotary instrumentation (NiTiR) technique would improve the cleaning and shaping of root canals and the quality of the root-filling. However, there is limited knowledge of the effectiveness of the technique when applied in general dental practice.

In two of four consecutive studies, the subjects were employees of a county Public Dental Service. The aim was to investigate the rate of adoption of clinical routines and the NiTiR technique: the output, and the qualitative meaning of successful change in clinical practice.
In the other two studies the aim was to investigate treatment effect and the cost-effectiveness of root canal treatment in a general population: the outcome.

Four hundred employees (dentists, dental assistants, administrative assistants and clinical managers) of a Swedish County Public Dental Service were mandatorily enrolled in an educational and training program over two years. Change of practice was investigated in a post-education survey. The NiTiR technique was adopted by significantly more dentists in the intervention county compared to a control county (77% and 6% respectively). Dentists in the intervention county completed root canal instrumentation in significantly fewer sessions than the dentists in the control county.

Eight in-depth interviews, two with each participant, (dentist, dental assistant, receptionist, clinical manager), were strategically selected for a phenomenological analysis. Four factors were identified as necessary for successful change: 1) disclosed motivation, 2) allowance for individual learning processes, 3) continuous professional collaboration, and 4) a facilitating educator.

A random sample of 850 performed root canal treatments was used for a study of treatment outcome; 425 before and 425 after the education and adoption of the NiTiR technique. Root-filling quality, periapical status and tooth survival were assessed on radiographs taken at treatment and at follow-up, ≥4 years later. Apical periodontitis was found in 34% of the teeth root-filled before the education compared to 33%, after. After the education, root-filling quality improved significantly, tooth survival was significantly higher, however, without a subsequent improvement in success rate post-education; 68% vs. 67%.

A micro-costing model was used to calculate the costs of root canal instrumentation, pre- and post-education, in the same sample used in the study of treatment outcome. Costs were lower post-education: by SEK 264 for teeth with one canal and SEK 564 for teeth with three or more canals. A reason for lower costs was that the NiTiR technique dominated after the education and required significantly
fewer instrumentation sessions. A cost-minimization analysis disclosed that root canal treatments undertaken post-education were more cost-effective.

In conclusion, there was only a partial relationship between output and outcome. Although root-filling quality improved significantly, the study did not show any association between the more frequent use of NiTiR and an improvement in remaining teeth with normal periapical status or success rate. However, the use of NiTiR was more cost-effective. These results are in accordance with previous findings of the so called efficacy-effectiveness gap in clinical practice: a high output is not predictive of a high outcome. The overall conclusion to be drawn from these studies is that further research is warranted to identify factors associated with improvement of the quality of endodontic care.

The general interpretation of the findings of these implementation studies is as important as the effects of the change in endodontic instrumentation: a clinically relevant and applicable intervention, introduced by experienced expertise under allowing learning and collaborating circumstances, disclosed clinicians’ motivation and facilitated implementation. The finding of qualitative differences between the questionnaire responses and the in-depth interviews suggest that a critical approach is warranted when comparing surveys and qualitative methods aimed at investigating qualitative experiences of change, due to their different epistemological premises.
POPULÄRRVETENSKAPLIG
SAMMANFATTNING

Det är angeläget att forskning och nya metoder används och utvärderas så att de gör största möjliga nytta för patienterna. Studier av utbildningar som tolkar och överför ny kunskap till klinisk vardag i syfte att åstadkomma förändrade rutiner visar att förändringsgraden i allmänhet är låg. Trots omfattande forskning är kunskapen begränsad om hur förändringar äger rum och hur effekten ska mätas. Det övergripande målet med avhandlingen var att studera en teoretisk och praktisk utbildningsinsats vars avsikt var att införa nya rotbehandlingsrutiner i en svensk folk tandvårdsorganisation, med fokus på förändrat arbetssätt, förändringsprocessen och förändringens behandlingseffekter.

En stor andel av rotfyllda tänder i svenska populationer uppvisar rotspetsinflammation (apikal parodontit). Eftersom tidigare studier har visat på ett samband med bristande rotfyllningskvalitet har det antagits att om rotfyllningar utförda i allmän tandvård kan förbättras med hjälp av ny teknik och nya rutiner kan det minska frekvensen av apikal parodontit. Kliniska studier har visat att flexibla rotkanalsinstrument av nickel-titan (NiTi), underlättar renningen av rotkanaler och förbättrar rotfyllningskvaliteten, men det finns ännu inget vetenskapligt stöd för att det skulle leda till mer effektiva behandlingar och bättre behandlingsresultat.

I de två första av fyra delarbeten undersöktes integreringen av NiTi-teknik och kliniska behandlingsrutiner samt upplevelsen av förändringen
bland folktandvårdens personal. I de två sista delarbetena studerades behandlingsutfallet och de hälsoekonomiska effekterna av utbildningen. Fyrahundra anställda (tandläkare, tandsköterskor och klinikledningspersonal) deltog i en teoretisk och praktisk utbildning under en tvåårsperiod. I en uppföljande enkätstudie jämfördes svar från tandläkare i interventionslänet med tandläkare i ett kontrollän. Tandläkare i interventionslänet använde NiTi-tekniken säkerställt oftare än tandläkare i kontrollänet (77% respektive 6%) och de behövde också färre behandlingsbesök för en rotfyllning.

I studien kring förändringsprocessen användes djupintervjuer genomförda vid två tillfällen med en tandläkare, tandsköterska, receptionist och klinikchef. Fyra faktorer visade sig vara nödvändiga och beroende av varandra för att en förändring skulle uppfattas som lyckad; 1) deltagarna skulle vara, eller bli, motiverade till förändring 2) i en process som tillåt individuell inlärning samtidigt som 3) olika yrkesgrupper kontinuerligt samarbetade i inlärningsprocessen, vilken 4) skulle underlättas av en trovärdig utbildare med kunskap om den kliniska vardagen och med positionell makt att genomföra förändringen.

Behandlingsutfallet studerades i 850 slumpmässigt utvalda tänder som blivit rotbehandlade, 425 rotfyllda före och 425 efter utbildningen. Rotfyllningskvalitet, käkbenets utseende och antalet kvarvarande tänder bedömdes röntgenologiskt vid rotfyllning och ≥4 år senare. Vid uppföljningen förekom apikal parodontit i 34% och 33% av tänder som rotfyllts före respektive efter utbildningen. Trots fler kvarvarande tänder och förbättrad rotfyllningskvalitet hade lyckandefrekvensen inte förbättrats, 68% före och 67% efter utbildningen.

Kostnaderna för att rensa och fylla rotkanaler undersöktes i samma material som i studien av behandlingsutfall. Efter utbildningen var kostnaderna 264 SEK lägre för tänder med en rotkanal och 564 SEK lägre för tänder med tre- eller flera rotkanaler. Skillnaderna i kostnader förklarades av att det krävdes färre behandlingsbesök efter utbildningen när NiTi-tekniken användes av fler tandläkare. Studien visade att rotfyllningar utförda efter utbildningen var mer kostnads effektiva.
Sammanfattningsvis kunde studierna delvis visa att integrering av ny teknik påverkade effektiviteten av behandlingarna. Efter utbildningen var rotfyllningarna mer kostnadseffektiva, rotfyllningskvaliteten bättre och fler tänder överlevde, men den ökade användningen av NiTi-teknik ledde inte till en minskning av apikal parodontit. Detta visar på ett fortsatt behov av studier av faktorer relaterade till det kliniska behandlingsutfallet av rotfyllningar utförda i allmäntandvård.

Studierna gav också ökad kunskap om upplevelsen av ett lyckat förändringsarbete. Förändringen upplevdes som kliniskt relevant och motiverande eftersom den infördes under former som tillåt individuell övning och samarbete mellan yrkesgrupper, och underlättades av en utbildare med ämnesspecifik och kontextuell kunskap. En viktig slutsats var också att resultaten från enkäter och djupintervju-studier inte kan jämföras utan att man samtidigt är kritiskt observant på de vetenskapsteoretiskt skilda bakgrunderna; att metoderna ger kvalitativt olika svar och fyller olika funktioner.
This thesis is based on the following papers, referred to in the text by their Romans numerals.


III Koch M, Wolf E, Tegelberg Å, Petersson K. Quality and long-term outcomes of endodontic treatment in general practice before and after an education in the NiTi rotary technique. Submitted to Int Endod J.


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DEFINITIONS AND ABBREVIATIONS

Efficacy: the extent to which a given intervention is successful in producing an intended effect under ideal conditions.

Effectiveness: the extent to which a given intervention is successful in producing an intended effect under everyday clinical conditions.

Efficiency: the extent to which a given intervention makes the best use of available resources.

Output: the success of an interventional program in terms of adoption of the strategy by the participants. Answers the question: “Have the specific activities been adopted?”

Outcome: the success of an interventional program in terms of clinical benefits. Answers the question: “Are the adopted activities having any effect on the problem?”

In the endodontic literature different procedures may be referred to by the same term. The following definitions apply in this thesis:

Root canal treatment is the cleaning, shaping and obturation of the root canals. This includes the treatment of teeth with either vital or non-vital pulps.

Instrumentation sessions are the treatment session/sessions in which the root canal system is cleaned, shaped and obturated (root-filled).
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AP</td>
<td>Apical periodontitis</td>
</tr>
<tr>
<td>CC</td>
<td>Control county</td>
</tr>
<tr>
<td>CMA</td>
<td>Cost-minimization analysis</td>
</tr>
<tr>
<td>IC</td>
<td>Intervention county</td>
</tr>
<tr>
<td>GDP</td>
<td>General dental practitioner</td>
</tr>
<tr>
<td>NiTiR</td>
<td>Nickel-Titanium rotary instrumentation</td>
</tr>
<tr>
<td>PAI</td>
<td>Periapical Index</td>
</tr>
<tr>
<td>PDS</td>
<td>Public Dental Service</td>
</tr>
<tr>
<td>SSI</td>
<td>Stainless steel instrumentation</td>
</tr>
<tr>
<td>SBU</td>
<td>Statens beredning för medicinsk utvärdering. Swedish Council on Health Technology Assessment</td>
</tr>
<tr>
<td>SoS</td>
<td>Socialstyrelsen. The Swedish National Board of Health and Welfare</td>
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INTRODUCTION

Implementation
The focus of implementation research is on the mechanisms by which an intervention functions (or fails to function) in its intended setting. Considerable funds are allocated for research and development of health technologies, but the findings are not always readily accepted by clinicians (Greenhalgh et al. 2004, Grol & Grimshaw, 2003, Nutley et al. 2008). Change is possible, and most interventions do have some effect, but achieve on average only a 10% change of practice behavior (Grol & Grimshaw 2003, SBU 2012). Even if change is achieved, its effectiveness must still be documented: adoption of change does not automatically lead to improved effectiveness in routine practice (Luce et al. 2010, O’Brien et al. 2008). The gap between research and practice is known as the efficacy-effectiveness gap, by which patients are denied the health benefits of new research findings or technological developments.

In a report of health care systems in seventeen countries, the Organisation for Economic Co-operation and Development (OECD) showed that 25-30% of surgical procedures were potentially dangerous and 15-30% inappropriate or unnecessary, meaning that the medical evidence did not justify the medical intervention (OECD 1994). Such gaps between available knowledge and clinical performance have been regarded primarily as a knowledge transfer problem, which could be solved by finding the appropriate strategies for channeling information more efficiently (Lomas 1993). As a consequence, there has been considerable investment in development of practice guidelines, based on available knowledge about alternative treatment, to
serve as standards: it is assumed that the recipients will comply with them. However, this does not seem to be the case. While guidelines appear to be important, they do not seem to be sufficient to improve practice (Grol 2001, Farmer et al. 2008).

Almost all successful improvements in clinical practice involve the practitioner’s assessment of the usefulness and relevance of research applied in the context of daily practice. Some examples may serve as illustrations. Clinicians, across professions, seem to judge knowledge differently, some forms being more credible than others: they perceive their own experiences or that of trusted colleagues to be highly relevant (Davis et al. 2010, Ferlie et al. 1999, Hader et al. 2007, Rycroft-Malone et al. 2004). Much clinical experience is tacit knowledge (such skills people unconsciously possess) which seems to be more respected than scientific research and clinical recommendations (Dopson et al. 2002, Grol et al. 2007, Nutley et al. 2008, Rycroft-Malone et al. 2002). The overall thrust of the literature is that learning is complex and context-dependent. Organizations which identify the need for new knowledge and modify their practice accordingly, while still valuing craftsmanship, skills and individual self-worth appear to be more successful in implementing change (Greenhalgh et al. 2004, McCormack et al. 2002, Wallin et al. 2006). With respect to dentistry, two Swedish studies have highlighted the importance of continuing learning for quality improvements, reflective practice and for professional job satisfaction (Berthelsen 2010, Ordell 2011).

There is a substantial knowledge gap with respect to the factors which determine behavioural change. On the premise that the participant’s perspective should offer deeper insights, research using participant observation studies has been proposed for gaining knowledge about why, and under which circumstances, change is achieved (Blackwood 2006).

However, the problem is not limited to bridging the gap between research and practice. The effect of adopted and correctly applied knowledge must also be evaluated (Heasman et al. 2011, Johansson 2010, Wensing et al. 2010). Publications in the field of implementation research have been concerned primarily with investigating achieve-
ments to change behaviour, but these studies are mostly unsupported by measurements of outcome (Estabrooks 2007, Grimshaw 2006). The definition of achievement of change is two-fold; the output is the actual integration of a change or the adherence to guidelines, which has to be distinguished from the outcome, which is what is expected in terms of improved health or cost reductions (Drummond et al. 2005, Estabrooks 2007, Grol & Grimshaw 2003, Wallin 2009, Wensing et al. 2010). A high output is not necessarily predictive of a high outcome. Applied in medicine and economics, evaluations of implementation programs should incorporate clinical outcome data, rather than extrapolating results from output data, or data taken from efficacy studies (Grimshaw et al. 2006, Heasman et al. 2011, Jönsson & Karlsson 1990, Luce et al. 2010, Weatherly et al. 2009). For the benefit of society, care providers and patients, it is essential to evaluate how well new research and technology work in everyday clinical conditions in comparison with achievements under ideal conditions (Graham et al. 2006, Greenhalgh et al. 2004, Grimshaw 2004, Grol et al. 2007).

The difficulties of introducing change to practice apply to most professions and are described in medicine (O’Brien et al. 2008, Wallin 2008) in policy (Hill & Hupe 2009, Johansson 2010, Schofield 2001) and in studies in the educational sector (Bolam 1994, Rickinson 2005). There is no evidence to support decisions about choice of implementation strategy or which interventions are most likely to be effective, in terms of relevance, costs and benefits (Greenhalgh et al. 2004, Grimshaw et al. 2006). Grol et al. (2007), among others, recommend more theory-driven research on effective change, in order to develop testable interventions and improve generalisability, while Oxman et al. (2005) argue from another perspective:

“We need less rather than more focus on high-level theories, less rather than more jargon, less dogmatism, more common sense, less theoretical work, and more rigorous evaluations that include direct measurement of important outcomes [...] The proof of the pudding is in the eating.”
Implementation studies and economic evaluation in dentistry
Compared to publications in the health sector, the overall impression from the relatively sparse studies of behavioural changes in clinical dentistry is that change in dental practice is equally unpredictable and that there are few outcome studies (Bjørndal & Reit 2005, Bonetti et al. 2006, John & Parashos 2007, Knutsson et al. 2001, van der Sanden et al. 2005). Economic evaluations in dentistry are undertaken primarily in three fields: demand, supply, and treatment and care programs, using mainly intermediate output evaluations (Oscarson 2006, Yule et al. 1986). The ideal outcome of any intervention in dental care would be an improvement in oral health.
Unfortunately such economic evaluations are relatively limited and lack appropriate and sensitive measures of change of health (Oscarson 2006, Sintonen & Linnosmaa 2000).

Setting for the thesis
The basis for this thesis was an implementation program, comprising both educational and training components, undertaken to introduce a new root canal instrumentation technique and associated organizational and clinical procedures, such as time-planning, routines for endodontic emergency treatments, the organization of equipment and hygiene aspects. One year after the intervention, the adoption rate was high. The background for investigating aspects of the intervention, with special reference to an evaluation of the process of implementation and a measurement of clinical and economic outcomes, is described in more detail below.

Process evaluation
Change of behaviour can be considered a psychological social phenomenon. When investigating the participants’ experiences of behavioural change after an implementation program, either quantitative or qualitative methodologies may be applied, with different instruments appropriate for the purpose: surveys, observational studies, narrative research and in-depth interview studies.

Quantitative methodology applies a natural science approach to social phenomena and is characterized by objectivity, repeatability and causality. The questionnaire survey is a typical instrument in
this tradition. The questionnaire allows for an independent-observer approach, for replication and statistical inferences. Quantitative methodology is alternatively denoted “natural sciences”, “positivist” or “empiristic”, by which the epistemological position is stated; a logical-empiristic theory of universal laws, theories, hypotheses and statistical testing. The aim is to verify elements of the “real” world or prove them to be false (Bryman 1984, Giorgi 1988).

Qualitative research, also denoted human science research, differs in the way that the world is explored from the perspective of the investigated subject, which requires close involvement of the researcher with the subject. Closely associated with this theory of science is the philosophy of phenomenology, which seeks to search for the meaning of a phenomenon as it is lived by other subjects (Giorgi 2009). By using participant observation (the in-depth interview is a typical instrument) the researcher gets close to the subject and so discovers objects, meanings or experiences as seen from the world of the other (Englander 2012, Giorgi 2009).

Analysis of data collected from in-depth interviews focuses on depth, richness and variability, as opposed to survey data, where claims of causal relationships, validity and reliability are made, according to the different epistemological positions. Hence, one method cannot be superior or more “correct”, than the other, as the relevant question is whether the method is appropriate in terms of its epistemological premise. The different methodologies will answer different questions: the natural scientist will search for verification, while the human science researcher searches for discovery: “What is it like?” (Applebaum 2012, Englander 2012).

The descriptive phenomenological human scientific method
For discovery of experiences of social phenomena, the descriptive phenomenological human scientific method, based on phenomenology and psychology is a legitimate approach (Giorgi 2009). According to Giorgi (2009) the demands of empirical research for objectivity, methodological rigour and intersubjective validation should also be required of qualitative methods. The method was developed for that purpose (Applebaum 2012, Giorgi 1988, 2009). Applebaum (2012) states:
“In essence Giorgi’s research method is founded on the assertion that psychology as a human science requires a praxis that offers an alternative to the empirical while equaling the empirical in its clarity of articulation, epistemology, and guidance for practitioners.” (p. 45).

The method meets basic scientific criteria by providing systematic, methodical, general and critical steps, and meets phenomenological validity because the steps are carried out by the researcher adopting a certain psychological attitude (a phenomenological attitude) towards data (Applebaum 2012, Englander 2012, Giorgi 2000) (The method is explained in more detail in the Materials and Methods section). The ultimate goal for using the method in this thesis was to find and describe the structure of the phenomenon which could be applied for the understanding of similar phenomena.

Although qualitative research methods based on phenomenological philosophy are highly appropriate in the field of process evaluation of implementation programs, to our knowledge no such studies have previously been undertaken. Neither has any study in the dental care sector previously focused on the descriptive phenomenological human scientific method.

Measuring and valuing outcomes
According to Oscarson (2006), the objectives of dental care are to preserve health in healthy people, to prevent disease and to offer an efficient treatment strategy for those already suffering from disease. Thus an ideal measure of treatment outcome, with respect to the effectiveness of any implementation program intended to improve dental care, would be a positive change in oral health (Sintonen & Linnosmaa 2000).

Root canal treatment
One field of clinical dentistry in which well-informed clinical decisions may have great implications for the cost-effectiveness of the treatment, is the technically complicated and time demanding treatment of diseases of the dental pulp and the periradicular tissues. These conditions are sequelae to caries or subsequent restorative pro-
cedures, dentinal cracks or dental trauma. Once bacteria are established in the pulpal space, the pulp tissue is inflamed. Irreversible inflammation and its sequel, pulpal necrosis and the inflammatory periradicular response, apical periodontitis (AP) has to be treated in order to prevent further infection (Ørstavik & Pitt Ford 1998). The purpose of the root canal treatment is to eliminate infection already present in the root canal or to prevent root canal infection, for example in cases of inflamed vital pulps. This is achieved by mechanical cleaning and shaping of the root canal space, the use of intracanal chemical agents, obturation of the root canal (root-filling) and by providing a seal to the oral cavity.

Successful caries-preventive strategies in Sweden have led to reduced caries among children and adolescents (SoS 2011a). Despite improved oral health in these groups however, the need for the resource- and time-consuming root canal treatments remains high. According to the Swedish Dental and Pharmaceutical Benefits Agency (Tandvårds- och läkemedelsförmånsverket, TLV) a total of 235,835 root-fillings were performed in Sweden during the period 2008-07 – 2009-06.

A successful outcome for root canal treatment is usually defined as the complete prevention or cure of disease (AP). As the condition is generally symptomless and located in the periapical area, it is diagnosed indirectly, from radiographs. Descriptive and visual criteria have been used for radiographic assessment of the periapical area. Strindberg (1956) used the results of an extensive clinical and follow-up study for a descriptive classification of the radiographic appearance; success, failure or uncertain. Based on a histologic and radiographic study by Brynolf (1967), Ørstavik et al. (1986) developed the Periapical Index (PAI) by which a visual reference five grade scale was used for assessment of the apical structures, ranging from normal periapical bone tissue to severe AP. The technical quality of the root-filling has been determined by evaluation of quality of the seal and the length, in combination, and in some studies only by length (Kirkevang & Hørsted-Bindslev 2002). Using strict criteria for treatment outcome, the number of successfully treated teeth can be calculated and compared, allowing for investigations and comparisons in terms of treatment success and cost-effectiveness. The PAI scoring systems allows such comparisons (Ng et al. 2007).
There is a high success rate for endodontic treatment in teaching and specialist clinics: after 3-8 years AP is present in only 9% to 17% of root-filled teeth (Ng et al. 2011a, Ricucci et al. 2011, Sjögren et al. 1990). In contrast, epidemiological studies in general practice report higher frequencies of AP in root-filled teeth: 25% - 43% (Frisk et al. 2008, Skudutyte-Rysstad & Eriksen 2006). According to Demant et al. (2012), this can be described as a gap between what can be achieved and what is achieved. The reasons for this gap have been investigated extensively and several factors have been suggested as associated with treatment outcome. Epidemiological studies have shown a strong association between inadequate root-filling quality and periapical status (De Moor et al. 2000, Eckerbom et al. 1989, Frisk et al. 2008, Kirkevang et al. 2004, Ridell et al. 2006). Given that most teeth affected by AP have previously been root-filled (Eckerbom et al. 2007, Frisk et al. 2008, Ödesjö et al. 1990) and that root-filled teeth have a high frequency of AP (Frisk et al. 2008, Ridell et al. 2006, Skudutyte-Rysstad & Eriksen 2006), it has been assumed that by optimizing the root-filling quality in general practice, treatment outcome as well as oral health would improve (Bergenholtz & Spångberg 2004, Frisk et al. 2008, Kirkevang & Hørsted-Bindslev 2002).

The influence of other factors, such as tooth-specific characteristics, preoperative periapical status, operative factors and type and quality of coronal restoration, has been comprehensively investigated. Several of these factors have been associated with treatment outcome (Ng et al. 2011a). However, according to Ng. et al. (2007), to date no major factor has been disclosed, mainly because of lack of uniformity of study designs, data recording and the format of outcome data. In particular, variations in the definition of success have hampered valid conclusions. However, taking these methodological deficiencies into account, the success rate for primary root canal treatment was reported to range from 68% to 85%, without any improvement over the last forty years.

Such factors as clinicians’ skills, attitudes and treatment decisions in relation to treatment outcome have also been extensively investigated (Bjørndal & Reit 2005, Bjørndal et al. 2006, Demant et al. 2012). And it has been suggested that the introduction of new instrumentation and obturation techniques would improve the quality of root-fillings and treatment outcomes.
The nickel-titanium technique in root canal treatment

The straightening of curved root canals represents a major problem during root canal preparation, mainly due to the lack of flexibility of conventional stainless steel instruments (SSI). In clinical studies, root canal instruments made of nickel-titanium alloy (NiTi), and especially those developed for rotary use (NiTiR), are reported to follow the canal curvature and clean and shape root canals more effectively, with fewer procedural errors (Cheung & Liu 2009, Pettiette et al. 1999, Schäfer et al. 2004). Several studies describe educational programs in NiTiR for general practitioners (Koch et al. 2009, Molander et al. 2007) and an improvement in the rate of adequate quality root-fillings after implementation (Dahlström et al. 2011, Molander et al. 2007). However, there are few clinical data available on outcome and the results are contradictory (Cheung and & Liu 2009, Marending et al. 2005, Ng et al. 2011a, Pettiette et al. 2001). To date, no studies have been published on the outcome of NiTiR root canal treatments performed in general dental practice.

Health economics evaluations

Health economics is a sub-discipline in economics, used to aid in decisions about the allocation of health care resources (Drummond et al. 2005, Maynard & Kavanos 2000). Perhaps the two most important elements in health economic research are concerns about equity (the distribution of health gains) in relation to limited resources, and the evaluation of effectiveness, which considers both the efficacy and the ability to improve health under clinical conditions. This field of economics research therefore has close ties with the development of policy: it often forms a basis for different policies on the management of limited health care resources (Drummond et al. 2005, FAS 2006). A relevant example is that since 2011 dental practice in Sweden has been subject to recommendations on adult dental care, whereby the National Board of Health and Welfare provides guidelines for clinical treatment alternatives, intended to aid in cost-effective treatment decisions offered to patients on equal terms (SoS 2011b).

There are four categories of economic evaluations. All include similar measurements of costs, but are distinguished by the different evaluations of outcome (Drummond et al. 2005)
There are four categories of economic evaluations. All include similar measurements of costs, but are distinguished by the different evaluations of outcome (Drummond et al. 2005)

Table 1. Types of economic evaluations

| Cost-minimization analysis (CMA) | Identifies the least costly alternative when the procedures under consideration are expected to have the same outcomes. |
| Cost-effective analysis (CEA) | Evaluates situations when both the costs and the outcome will differ. The costs are calculated in monetary units, and consequences in units relevant to a disease-specific effect. Two perspectives emerge: the best effect for a given amount of resources, or the less costly alternative for the same effect. |
| Cost-utility analysis (CUA) | Similar to the CEA but is not disease-specific and allows for comparison of different consequences (quantity and quality of life). |
| Cost-benefit analysis (CBA) | A full economic evaluation which does not require a comparison of alternatives. It is concerned with whether a programme is worthwhile, assigning monetary values to both costs and outcomes in order to disclose whether the benefits exceed (justify) the costs. |

Health economics in dentistry

In a review from 2000, Sintonen and Linnosmaa concluded that economic evaluations in the dental field are relatively limited, and suffer from methodological deficiencies such as omission of relevant cost items, poor quality of data, lack of discounting and handling of uncertainties and lack a measure of oral health.

Health economic studies concerned with cost-evaluation in endodontic care are even more limited, and have primarily focused on the cost-effectiveness of preserving a tooth by performing a root canal treatment compared with tooth extraction and prosthetic replacement (Balevi & Shepperd 2007, Pennington et al. 2009). According to Drummond et al. (2005), in a full economic evaluation the
difference in costs is compared to the difference in consequence in an incremental analysis which does not apply to a CMA. However, for comparison of alternative root canal instrumentation techniques aimed at treating the same disease and expected to have similar outcomes, a CMA is an appropriate method. Thus, CMA was the method chosen for economic evaluation in this thesis.

As the CMA considers only costs, the calculation of the equipment specific to root canal treatments requires a full description of the costs of alternative techniques. For that purpose a micro-costing model is useful, taking very precise cost estimates into consideration (Evans & Hurley 1995).

There do not appear to be any studies of cost calculations of root canal instrumentation in general practice, taking monetary and outcome measures into consideration. Nor do there seem to be any studies comparing different techniques in relation to cost-effectiveness and treatment outcome.

**Rationale for the studies**

To summarize, there is a paucity of applied research incorporating evaluations of both output and outcome in the research design (Estabrooks 2007, Grimshaw *et al.* 2006, Jönsson & Karlsson 1990, Naidoo & Wills 2000, Weatherley *et al.* 2009).
This thesis is an implementation study of an intervention in the form of a comprehensive educational and training program in endodontics in a Swedish Public Dental Service organization. The overall aims were to assess the extent to which the intervention was successful in achieving change in practice, to analyze the factors determining adoption of the change, and to investigate the clinical effects of the change in practice.

The specific aims were to:

- Survey endodontic routines and the adoption of the NiTiR technique in the Public Dental Service of two Swedish counties, after a comprehensive education and training program in one of the counties.
- Explicate and describe the meaning of the phenomenon, “The experience of successful clinical and organizational change in endodontic practice following a comprehensive implementation program, including the integration of the NiTiR technique.”
- Investigate root-filling quality, periapical status, tooth survival and treatment outcome in teeth treated pre- and post-education, at treatment and ≥4 years after treatment.
- Compare the costs and number of instrumentation sessions, pre- and post-education, for root canal treatments performed by the participating dentists.
MATERIALS AND METHODS

Setting
The County of Sörmland is located in central Sweden and has around 270,000 residents. It is a rural, industrial and administrative area, with small municipalities, mainly small towns and a few medium-sized cities. The educational level is somewhat lower than the national average and unemployment rates are higher (Research & Development Centre, Sörmland County Council 2011). Dental care is provided by PDS clinics and private practitioners. The PDS serves 36% of the adults and 92% of the children in the county, in 16 general dental clinics and in 4 specialist dental clinics (year 2012).

The starting point of the thesis was an intervention in the form of an educational and training program conducted during the years 2003 and 2004, aiming at implementing contemporary endodontic routines and the NiTiR technique in the Public Dental Service. Approximately 400 employees (dentists, dental assistants, dental hygienists, administrative personnel and management teams) from 16 general and 2 specialist clinics were enrolled in the program. In all, 91 dentists participated: 69 were in continuous employment from the start of the intervention and throughout the program. The course was mandatory and attrition was low. The intervention elements in the educational and training program are shown in Paper I, Table 1, categorized (slightly adapted) according to strategies described by Grol & Grimshaw (2003).

The author, a Senior Consultant in endodontics, visited the clinics in introductory meetings to present the endodontic program. One-day
seminars comprising theoretical education were provided for all dentists. Two-hour seminars were additionally provided at the participants’ base clinics for all personnel, when dentists also received chairside, hands-on training in the ProFile® system (Dentsply Maillefer, Baillagues, Switzerland). Assisting personnel were involved for discussions about practical routines. Throughout the educational intervention, the process was monitored regularly with on-line published practical recommendations and e-mail feed-back.

Four consecutive studies were conducted to evaluate the output and outcome of the intervention. An overview of the subjects and methods used in the different papers is presented in Figure 1.

Figure 1. Overview of subjects and methods in Studies I – IV.

Subjects
Participating personnel (I, II)

Study I
In 2005, one year after completion of the educational programme, a post-intervention questionnaire survey was conducted, including all ($n = 195$) public dentists in two counties;
• Sörmland, the intervention county (IC) \( n = 98 \)
• Västmanland, the control county (CC) \( n = 97 \).

In the CC, no educational programme was provided. The counties were otherwise equally exposed to the advertising of the technique and continuing education courses.

**Study II**

Eight interviews with four participants were purposively selected for a descriptive phenomenological analysis from a previous study based on the qualitative content analysis method (described in the data collecting section).

The participants were selected according to the overall inclusion criteria:

• they had participated in the education and training course
• they were still employed in clinics where the new clinical routines and the NiTiR technique had been implemented

and to the following specific criteria for phenomenological human scientific research concerning the interviews (Giorgi 2009):

• they included a description of the phenomenon
• they had the required qualitative depth and variation necessary for phenomenological analysis
• they provided internal variation according to occupational category

The inclusion criteria resulted in the selection of four Swedish-born female participants; a GDP, a dental assistant, an administrative assistant and a clinic manager aged 46-54 years, with 18-30 years’ professional experience. There was no deliberate selecting of only female participants.

**Participating patients (III, IV)**

A random sample originating from the county population was used for both studies. After a power calculation, a total of 850 root canal treatments (425 from each year) were randomly selected from all
1301 root canal treatments performed in 2002 and all 1231 root canal treatments performed in 2005. Only root canal treatments undertaken by dentists employed both before and after the intervention were included. A flowchart over Studies III and IV, are presented in Paper III, Figure 1 and Paper IV, Figure 1.

Differences occurred in the number of teeth excluded because in Study III, but not in Study IV, adjustments were made for patients who contributed with two root canal treatments. Also, some radiographic images were accessible, although the corresponding record notes were missing, and some record notes were accessible although the corresponding radiographic images were missing.

**Data collection**

**Questionnaire (I)**

A post-intervention questionnaire was developed for the purpose of the study and a pilot version was presented to five dentists participating in a single-site focus group study. The focus group methodology allows us to explore how the views of several participants emerge during discussions. The interviews were conducted by a moderator (the first author), and a second moderator (an assistant researcher) who was responsible for taking notes. During these interviews, suggestions for improvements were discussed, ending in a modified final version. The survey was in the form of a postal questionnaire, preceded by a notification letter to each dentist, and followed by reminders to non-responding dentists after four weeks.

The questionnaire included 25 questions, identical for both counties, except for questions put to the dentists in the IC county, asking about their participation in the educational program and whether they were familiar with current recommendations for emergency endodontic treatment.

*The demographic variables* included: sex, age, years in profession, experience of continuing education and the frequency of endodontic treatments in clinical practice.

*The variables relevant to quality protocols* in endodontic practice included: the prognostic assessments, the use of rubber dam, determi-
nation of working length, the use of irrigation and inter appointment
dressing and postoperative follow-up routines.

*Adoption of the new endodontic technique* was assessed by the
variables: instrumentation technique, number of treatment sessions
needed to complete instrumentation, root-filling technique and atti-
tudes to conventional and NiTiR techniques.

The questionnaire is presented in Appendix A.

**In-depth interviews (II)**
Fifteen participants were invited by the interviewer (MK) to par-
ticipate. All accepted and two in-depth interviews, each of approxi-
mately one hour’s duration, were conducted with each participant.
An interview guide was used, focusing on the participant’s experi-
ences of events before and during the implementation program. The
second interview provided an opportunity for both researcher and
informant to reflect on the first interview. An audio copy of the first
interview was offered the participants to listen to before the second
interview. All interviews were recorded and transcribed verbatim.
The interview guide is presented in Paper II, Table 1.

**Collection of radiographs (III)**
Radiographs from the treatment session in 2002 and 2005 and
from a follow-up examination 2009, were retrieved from the Public
Dental Service clinics, and in cases of missing follow-up radiographs,
patients were recalled for an examination. Sixteen clinics used ana-
logue film radiography and two used digital radiography.

**Radiographic evaluation**
Tooth- and operative-specific findings were registered for each tooth
at treatment and at the follow-up examination: periapical status,
root-filling quality and marginal bone level. At follow-up, type and
quality of the final restorations and type of posts were also registered.
Two specialists in endodontics independently read the radiographs,
and a third specialist evaluated cases of disagreement, for a majority
decision to be made.
The *periapical status* of the root-filled teeth was evaluated according to the Periapical Index (PAI) (Ørstavik *et al.* 1986) (Table 2). Before using PAI the observers were calibrated against 100 reference radiographs until an observer/reference agreement with a Kappa value >0.61 was reached.

**Table 2. Criteria for the Periapical Index (PAI)(Ørstavik *et al.* 1986) and sealing quality and length of the root-filling.**

<table>
<thead>
<tr>
<th>Periapical status (PAI index:</th>
<th>1 = normal periapical structures</th>
<th>2 = small changes in bone structure</th>
<th>3 = changes in bone structure with some mineral loss</th>
<th>4 = periodontitis with well defined radiolucent area</th>
<th>5 = severe periodontitis with exacerbating features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealing quality, scores:</td>
<td>1 = adequate seal (no visible voids laterally or apically to the root-filling)</td>
<td>2 = inadequate seal (visible voids laterally or apically to the root-filling)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apex distance, scores:</td>
<td>1 = adequate (root-filling ending ≤2 mm from radiographic apex)</td>
<td>2 = short (root-filling ending &gt;2 mm from radiographic apex)</td>
<td>3 = overfilled (root-filling material visible in the periapical area)</td>
<td>4 = apical surgery and retrograde filling</td>
<td></td>
</tr>
</tbody>
</table>

Criteria for marginal bone level, type and quality of coronal restoration and type of posts are presented in Paper III, Table 1.

**Collection of record data and cost calculation (IV)**

This second effectiveness study dealt with the costs for root canal instrumentation. For the purpose of the study, two sets of data were necessary: a measurement of quantities (the number of instrumentation sessions), and costs.

The number of instrumentation sessions was counted by MK and a dental assistant for each root canal treatment, in the notes of the patient records. Only instrumentation sessions were counted: all other appointments were excluded, as long as no further instrumentation was undertaken. The two observers each counted all records, and in cases of disagreement, consensus was reached after discussion.
In accordance with practice in the County Public Dental Service, the duration of one instrumentation session was estimated to be one hour.

Costs were categorized as a) personnel costs b) material costs related to instrumentation sessions and c) overhead costs, which were costs not directly related to dental care (considered to be unaffected by instrumentation technique and thus excluded).

*Personnel costs* were staff cost estimates, based on Public Dental Service salaries in the county of Sörmland in 2011, giving a total hourly personnel costs of SEK 893 (USD 142).

*Material costs related to instrumentation sessions* were based on prevailing market prices (year 2011). Each component of resource use was estimated, and a unit cost was calculated in a micro-costing model (Drummond et al. 2005). The average cost related to one instrumentation session was calculated separately for treatments of teeth with one, two, or three or more canals.

Direct and indirect costs associated with the change in practice were also calculated, but not included in the CMA.

**Data analysis**

*Questionnaire (I)*
The analysis comprised comparison of the responses to the questionnaire from the intervention and control counties.

*Qualitative analysis (II)*
The interviews were analyzed according to the phenomenological human scientific method, comprising four consecutive, methodological steps (Giorgi 2009). The Steps 1 and 2 are general for in-depths interview methodologies, whereas Steps 3 and 4 are of particular methodological concern, and require a more comprehensive explanation, as presented below.

Step 1. The interviews are read several times in order for the researcher to grasp a sense of the whole.
Step 2. Meaning units are identified, that is, marking the point at which a change of content occurs in the text. In Picture 1 a meaning unit is marked by a blue box. In Picture 2 the meaning unit is magnified.

Picture 1. A meaning unit is identified

The meaning unit revealed in Step 2 consists of raw data which are personal and empirical, experienced by the individual in everyday life (Picture 2). However, personal experience is not of interest for descriptive phenomenological human scientific research. What is of interest is general knowledge, disclosed by the researcher adopting a certain scientific critical perspective towards the interviewee’s personal experiences. Giorgi (2010) stated:
“A disciplinary perspective (psychology, education, nursing, etc.) is not the same as an everyday perspective.” (p. 13)

Intervjuperson: Och vi, vi HAR faktiskt varit på någon kurs innan ... med maskinell rensning som var mycket omständligare, nu kommer jag inte ihåg vad den hette, men då (sväljer) kände man inte att det var, att det här var nåt för oss. Om jag pratar för men egen del så tyckte inte jag att det var nåt för mig då, för det var, det var så många olika moment, så det blev ingen för för förenkling.

Participant: And we, actually we DID attend a course previously ... with rotary instrumentation which was much more complicated, just now I don’t remember what it was called, but then (swallows) one didn’t feel that, that this was anything for us. Speaking for myself, then I didn’t think it was something for me, because there were, there were so many different steps, so there just wasn’t any simplification.

*Picture 2. Meaning unit to be transformed*

To be able to break from this everyday perspective the researcher adopts a phenomenological attitude, to seek a higher-level characteristic of the experienced phenomenon. A phenomenological attitude contains two elements; first, “bracketing”, by which the researcher’s own experiences, presuppositions or judgments are minimized and not engaged during the data analysis, and second, the researcher applies a method to seek an invariant structure of the phenomenon; the approach of so-called eidetic variation, disclosed by the question: “What does this particular meaning unit tell me about the experience of the phenomenon?”. The researcher varies the answers until an expression is found that captures the most precise meaning on a general level. An example using data in Study III is presented in Step 3.
Step 3. The transformation of the meaning unit in Picture 2 is presented in Table 3. All collected data are taken into account without any selectivity, regardless of whether or not the data appear to be relevant on first impressions. This is the core of the method. Note that there is no speculative or undisclosed influence by the researcher on the description because of the method of “bracketing”. The second column repeats the words in the first column, except that the third-person expression is used in a language more sensitive to the researcher’s perspective. In the third column the transformed meaning unit is disclosed by the use of eidetic variation, answering the above question of what the particular meaning unit reveals about the experience of the phenomenon.

Table 3. The meaning unit is transformed

| Participant: And we, actually we DID attend a course previously … with rotary instrumentation which was much more complicated, just now I don’t remember what it was called, but then (swallows) one didn’t feel that, that this was anything for us. Speaking for myself, then I didn’t think it was something for me, because there were, there were so many different steps, so there just wasn’t any simplification. | The participant spontaneously presents another perspective of an experientially related sense of simplification related to the usefulness of the technique. She recalls that the personnel at the clinic had previously attended another course in root canal rotary instrumentation technique, but she is unable to remember the name of the technique. She initially refers to the whole group of colleagues and their experiences of the technique, and their perception of the technique as more complicated. So they didn’t feel that this technique was something they wanted to adopt. When the participant then chooses to describe her own experience, she states that in her opinion, the technique contained too many steps, and did not provide any simplification; so she didn’t see that it was anything for her to consider adopting. | Motivation was disclosed by the implicitly expressed expectations which revealed dissatisfaction with previous experiences. |
Step 4. At the end of the third step there is a series of transformed meaning units contained from each meaning unit in the interview. Based on these transformations the structure of the phenomenon is disclosed (Giorgi 2009). In order to determine which transformed meaning units are essential for the phenomenon and which are not, the approach of eidetic variation is applied again by the researcher. This time the purpose is to find the truly invariant characteristics taking all transformed meaning units into account, to find the inter-dependent constituents of the general structure of the phenomenon. Giorgi (2009) explained the importance of the constituents for the whole structure in the following way:

“An important criterion in this process is whether the structure would collapse if a potential constituent were removed. If it does, the constituent is essential; if the structure does not collapse, then the constituent is not essential.” (p. 199)

Step 4 ends with a description of the general structure, explicated in such a manner that not only the necessary constituents are presented, but a disclosure of how they are interrelated.

Steps 1 - 3 were undertaken independently by the researchers and Step 4 by the researchers together.

Radiographic follow-up study (III)

AP
In analysis of periapical status, PAI scores 1 and 2 represented normal periapical status, and scores 3, 4 and 5 represented AP. Further analyses were undertaken in which scores 4 and 5 represented definite AP (Ørstavik et al. 1986, Ørstavik 1996).

Root-filling quality
A root-filling assessed as adequate for both seal and length, was classified as Adequate Overall Quality. A root-filling classified with any other quality score was classified as Inadequate Overall Quality.
Cost-minimization analysis (IV)
It was assumed that root canal treatments undertaken before and after the intervention would achieve at least identical outcomes: thus a cost minimization analysis (CMA) was appropriate (Drummond 2009). Only the costs associated with the instrumentation procedures in root canal treatments undertaken before and after the implementation program were compared. The cost was calculated as follows:

Personnel costs per hour + mean material costs related to one instrumentation session x mean number of hours*.

*One instrumentation session was calculated to last one hour.

Alternative assumptions about time spent per session were tested in a univariate sensitivity analysis.

Statistical analyses (I, III, IV)
All statistical tests were two-tailed. The significance level was set at 5%. The Statistical Package for the Social Sciences (SPSS, Versions 13-19 for Windows; SPSS Inc., Chicago, Il, USA) (I, III, IV) was used.

Sample size calculation was performed to achieve an 80% chance of detecting a difference in means of 10% in frequency of AP, and in 0.1 instrumentation sessions in root canal treatments in teeth root-filled before and after the implementation program.

Descriptive statistics data were used for presenting percentages for prevalence and distribution of variables (I, III, IV).

Levene’s Test for Equality of Variances and t-test for Equality of Means were used for inter-group differences (I, III, IV).

The Chi²-test was used for for comparison of qualitative variables/non-parametric variables for inferences between groups (I, III, IV). For observations with expected value <5, Fisher’s exact test was used (I, III, IV).

Kappa statistics were used to evaluate inter- and intra-observer variation in Study III (radiographic scores of periapical status, root-filling
quality, marginal bone level, type and quality of coronal restorations, type of post). Total agreement, in percentages, was calculated.

To estimate factors associated with the frequency of AP at follow-up, logistic regression was used to calculate odds ratios and 95% confidence intervals (CI) and both crude (cOR) and adjusted odds (aOR) ratios were estimated. In the adjusted analysis we used a multivariate logistic regression model where the variables; type of tooth, PAI and marginal bone loss at treatment, and the variables; sealing quality, length of the root-filling, Adequate Overall Quality and type and quality of coronal restoration at follow-up were entered simultaneously. (III)

**Ethical considerations**
The Regional Ethical Review Board at Karolinska Institute, Stockholm, approved the study (Registration no: Dnr 2008/1723-31/3).
RESULTS

Output of the implementation program (I, II)
Questionnaire survey (I)
In this first of two output studies, change was assessed by means of a questionnaire survey of dentists employed by the PDS in two counties, after the dentists in one of the counties had participated in a comprehensive implementation program. The results thus are based on self-reported data.

The response rate to the questionnaire was 92% (n = 91) in the intervention county and 83% (n = 81) in the control county. Of the 23 non-participating dentists, 11 had relocated, retired or become specialists, and 12 declined to participate. The internal validity (completion of all questions) was 99 - 100%. There were no differences between the counties with respect to distribution of gender, mean age, or mean years in the profession.

Quality procedures in clinical practice
The quality procedures in endodontics applied by dentists in the two counties were similar. A majority, 72% (IC) and 66% (CC) reported that they always used rubber dam. The determination of working length, the use of 0.5% NaOCl as a canal irrigant, and calcium hydroxide as an intra-canal dressing, was reported by 98-100% of the dentists. It was not routine practice to inform the patient of the expected treatment outcome. One third of those reporting “no routine” were unable to give any explanation offered by the multiple choice options and answered: “other reason”. Postoperative radiographs were taken before crown therapy, or in cases of clinical symptoms.
Patterns of NiTiR use
The NiTiR technique was fully adopted by significantly more respondents in the IC (77%) than in the CC (6%), (p<0.001). 12% of the dentists in the IC used NiTiR in combination with SSI (Paper I, Figure 2).

Treatment sessions and root-filling technique
There was a significant (p<0.001) difference between the IC and CC with respect to the number of treatment sessions required to complete instrumentation (Paper I, Figure 3).

Sealer use was an established routine in both counties; in combination with single-cone obturation in the IC, and cold lateral compaction technique in the CC.

Reasons for using different techniques
Access to practical education and training, a perception of improved quality of root-fillings and less tiring procedures were considered to be important factors for adoption of the new technique. Dentists using conventional techniques expressed the lack of training in NiTiR as a reason for non-adoption, but also a perceived sense of greater control in the conventional technique and concerns about the risk of fracture of NiTi instruments.

Qualitative aspects of the successful change process (II)
In this second output study, the aim was to explicate and describe the meaning of the phenomenon: “The experience of successful clinical and organizational change in endodontic practice following a comprehensive implementation program, including the integration of the NiTiR technique”.

The final step of the analysis (Step 4) revealed a general structure of the phenomenon. Four constituents could be found in all of the participants’ experiences of the phenomenon, that is, the qualitative aspects of the successful change process. None of the constituents could in itself describe the whole phenomenon, and a specific account of the constituents holds the general structure together:
**Disclosed motivation.** Motivation emerged as a key constituent for a successful change process. For those participants who were not motivated before the intervention the advantages of the change emerged during the course. For those already expecting improvements, motivation was reinforced by the explicit fulfillment of the applicability of the change process on overall patient care, improvement in daily work routines and enhancement of treatment quality.

**Allowance for individual learning processes.** Two aspects of the learning processes emerged: 1) the participants were allowed to evaluate the applicability of the new routines by being able to practice the new routines individually, on their own terms 2) the learning processes allowed for an incorporation of the new routines to tacit, embodied, knowledge.

**Continuous professional collaboration.** Involving all personnel in the intervention ensured that everyone received the same information. This had two important effects: it positively affected daily routines, and circumvented the issue of participants having to motivate other occupational groups.

**A facilitating educator.** Successful change required an educator not only competent with respect to scientific knowledge and clinical expertise, but also one who comprehended the potential advantages of the particular methods, and its applicability to the existing culture.

The relationship between the constituents forms the general structure of the phenomenon:

Successful organizational and clinical change in endodontic practice, achieved after a comprehensive implementation program, including the integration of the NiTiR technique into clinical practice, was characterized by a complex context of collaboration. The participants expressed implicit or explicit motivation throughout the change process. The implicit motivations revealed dissatisfaction with previous routines and optimism that improvements might be possible. The explicitly expressed expectations anticipated advancement of clinical procedures and outcomes,
thus motivation was revealed by clinical relevance. Fulfillment of these expectations required an individual learning process which provided adequate time and resources, and intra- and interprofessional, spontaneous continuous collaboration in the clinical context. The overall change process had to be facilitated by a person with the authority to implement such change: someone in whom the participants had confidence, acknowledged not only for clinical expertise and decisional power, but also with insight into the context into which change is directed.

**Outcome of the implementation program (III, IV)**

**The outcome of root canal treatment (III)**

In this first of two studies investigating the effectiveness of the educational and training program, the aim was to investigate and compare the effect of implementation of the NiTiR technique with special reference to root-filling quality, periapical status, tooth survival and treatment outcome, $\geq$4 years post-treatment.

**Reliability**

The mean observer agreement was 89.6\% of all observations.

**Registrations at treatment and follow-up**

Of the 414 teeth root canal treated pre-education and the 416 teeth root canal treated post-education, treatment radiographs were available for 265 (64\%) and 325 (78\%) teeth respectively. At follow-up, 226 (55\%) and 293 (70\%) radiographs were available (Paper III, Figure 1).

There were no differences in distribution according to sex, age or type of tooth between the patients treated pre- and post-education.

**Outcome of root canal treatment pre- and post-education**

At *treatment* and by *follow-up*, root-filling quality was significantly better for the teeth treated post-education, with respect to the following criteria: adequate sealing quality, adequate length and Adequate Overall Quality. Adequate Overall Quality was reached in 33\% and 48\%, respectively, of the teeth treated pre- and post-education (Paper III, Tables 4, 5).
At treatment, PAI (3+4+5) was registered in 62% and 61% and at follow-up in 34% and 33%, respectively, of the teeth treated pre- and post-education (Paper III, Tables 4, 5).

A majority of the root-filled teeth were restored with direct composite restorations, 80% and 84%, respectively, of the teeth treated pre- and post-education (Paper III, Table 6). The quality of coronal restorations was adequate in 80% and 85%, respectively.

Comparison of treatment outcomes for teeth root-filled pre- and post-education
Treatment and follow-up data were available for 229 (55%) and 288 (69%) of the teeth treated pre- and post-education.

Significantly more teeth root-filled pre-education compared to post-education were extracted at follow-up (p = 0.000).

By follow-up, no significant differences comparing the teeth root-filled pre- and post-education were observed, neither for the outcome measure remaining teeth with normal periapical status (PAI 1+2) 58% and 64% respectively, the outcome measure success rate, 68% and 67%, nor for failure rate (PAI 4+5), 19% and 16%, respectively.

Multivariate logistic regression analysis
AP by follow-up defined as PAI (3+4+5) was significantly associated with:

- molar teeth, for teeth treated pre-education (aOR 3.4, CI 1.1 - 10.2)
- pre-operative PAI (4+5) for teeth treated pre- and post-education (aOR 2.8, CI 1.2 - 6.5) and (aOR 5.3, CI 2.4 - 11.5)
- marginal bone loss ≥1/3 of the root length for teeth treated pre- and post-education (aOR 4.1, CI 1.2 - 13.3) and (aOR 0.3, CI 0.08 - 0.8)
- AP (PAI 3) (aOR 3.2, CI 1.4 - 7.5) and inadequate root-filling quality (aOR 2.7, CI 1.4 - 5.3), were significantly associated only for teeth treated post-education.
The main findings were that pre-operative definite AP (PAI 4+5) was associated with both AP and definite AP, by follow-up, both pre- and post-education. Inadequate root-filling quality was significantly associated with AP by follow-up, only in post-education cases (Paper III, Tables 2, 3).

Cost-minimization analysis (IV)
In this second outcome study, of the effectiveness of the educational and training program, the aim was to compare the costs for instrumentation, and the number of instrumentation sessions, for root canal treatments undertaken before and after adoption of the NiTiR technique.

Costs for instrumentation - a micro-costing model
The mean cost for one instrumentation session was calculated separately for the NiTiR and SSI techniques in a micro-costing model (Appendix B).

The costs for root canal instrumentation post-education were lower than for pre-education treatments. The differences in costs were SEK 264 (USD 42) for teeth with one canal, SEK 6 (USD 1) for teeth with two canals and SEK 564 (USD 90) for teeth with three or more canals (Paper IV, Table 3). The major determinant of the costs was the number of instrumentation sessions. Root canal treatments provided under the scheduled fee for endodontic treatment of teeth with one canal (p<0.000) or three or more canals (p<0.000) were completed in significantly fewer instrumentation sessions post-education. Root canal treatments in teeth with two canals, however, showed no significant difference in number of instrumentation sessions (Paper IV, Figure 2).

Direct and indirect costs for implementing the NiTiR technique in the Public Dental Service were estimated at SEK 2.1 million (USD 339,000), mainly in the form of indirect costs, i.e. loss of revenue from clinical treatment of patients while the dentists participated in the theoretical and practical course.
Sensitivity analysis
To test for the uncertainty about the time spent per session, a univariate sensitivity analysis was conducted. A critical threshold was found, showing that costs for instrumentation after the implementation program will remain lower, as long as the total time for instrumentation does not exceed that in pre-intervention root canal treatments, by more than 18 minutes for teeth with one canal, and 38 minutes for teeth with three or more canals.
DISCUSSION

Main findings
In this series of studies, the implementation programme achieved a high integration of rational clinical routines and adoption of the NiTiR technique. Successful change in practice was perceived to be attributable primarily to the fact that relevant, applicable innovations were introduced into clinical context under allowing learning and supervised conditions, which disclosed clinicians’ motivation and facilitated implementation. After the educational intervention, root-filling quality improved significantly, tooth survival was significantly higher and root canal treatments were more cost-effective. However, no corresponding improvement in periapical status was disclosed.

Methodological considerations
Quantitative and qualitative methods were used. Two instruments were developed for the specific purposes of the studies; a questionnaire (I) and a micro-costing model (IV). In two studies validated methods were used (II, III).

Studies of the output of the implementation program through a questionnaire survey and in-depth interviews (I, II)
Questionnaire (I)
The results of the questionnaire were based on self-reported data by dentists in two Swedish PDS organizations. The value of a questionnaire survey depends on the accuracy with which the questionnaire measures what it is intended to measure (content validity), the representativeness of the results (external validity) and the way it is
affected by bias (Boynton & Greenhalgh 2004). The response rate was high in both counties, and high internal validity was achieved: 99% to 100% of all questions were answered by all dentists. Careful pre-survey notification and a general interest in the NiTiR technique may have been important determinants of the high response rates.

To our knowledge no valid instruments are available for surveying endodontic routines, and a questionnaire therefore had to be developed. After pre-test in a pilot study it was subsequently revised. Rephrasing was suggested in a few questions and more multiple-choice alternatives were listed. Questions about adoption of a new technique have been used in previous research and were modified only slightly (Barbakow & Lutz 1997, Bjørndal & Reit 2005, Hommez et al. 2003, Jenkins et al. 2001, McColl et al. 1999, Parashos & Messer 2004). The term face validity is used to describe attempts to develop questions in this manner, but its legitimacy is criticized: “the appearance of validity is not validity” (Downing & Haladyna 2004). As validity refers to the meaningfulness of the interpretation of an assessment, the results of the present questionnaire should be interpreted with some caution.

One limitation affecting the validity of survey research in general is the social desirability bias, meaning that responders tend to answer the questions according to a socially agreed norm (Nederhof 1985, Sjöström & Holst 2002). Thus, bias would be introduced if the dentists answered what was expected of them in the clinical situation, instead of what they actually do. The statement about the use of rubber dam was at risk for response bias. To the statement “I use rubber dam” (no. 13, Appendix A), 72% (IC) and 66% (CC) answered: “Always”. A recent survey of common practice of a similar sample of Swedish dentists reported that the use of rubber dam in emergency situations was low, but increased during continued treatment (Gruffman et al. 2009). As the dentists were asked more generally about the use of rubber dam in the present study, the potential risk of over-reporting must be considered.

Questions no. 7 and 8 (Appendix A) listed the reasons for adoption or non-adoptions of NiTiR in closed- and open-format alternatives.
Only a few dentists took the opportunity to comment freely on their experiences and this limited the information. According to the closed-format answers the overall reasons were related to technical aspects, which is in accordance with previous findings (Barbakow & Lutz 1997, Parashos & Messer 2004, Reit et al. 2007).

It is concluded that the questionnaire served its purpose, as an instrument for investigating non-tendentious clinical routines. However, clinical inferences could not be drawn for the specific purpose of exploring the qualitative experiences of adoption or non-adoption of NiTiR technique: a different research methodology was required, based on another epistemological position (Boynton & Greenhalgh 2004, Bryman 1984, Haynes et al. 1995).

The qualitative research method chosen for this purpose is described in the following section.

The descriptive phenomenological human scientific method (II)

In this study a valid qualitative research method was used; the descriptive phenomenological human scientific method (Applebaum 2012, Giorgi 2009). In Study I, participation in the questionnaire survey had been limited to dentists. However, in order to explore as much variation of the experiences of clinical change as possible, the subjects selected for Study II represented participants with a range of responsibilities in the clinics. As the descriptive phenomenological human scientific method is based on depth research strategies rather than sampling strategies, the strategic selection of four participants provided the depth and variability required for the specific purpose of the study (Englander 2012, Giorgi 1988).

The qualitative method revealed essentially different experiences of change in clinical practice, compared to the questionnaire survey. Clinical relevance, applicability, and aspects of the implementation process were cited as factors disclosing motivation for change. In contrast, the dentists’ responses to the questionnaire emphasized technical aspects. Although the questionnaire could be claimed to reflect primarily aspects of the dentists’ clinical procedures, two dentists also described their experiences in the interviews. The con-
Contrast in findings between the questionnaire and interview method is important, as it indicates a potential weakness in surveys investigating experiences and attitudes. It is not a question of whether one method is more correct than the other, but of the different epistemological positions on which the methodologies are based (Bryman 1984, Englander 2012, Giorgi 2010).

**Studies of the outcome of the implementation program (III, IV)**

**Radiographic follow-up study (III)**

The strength of this study is the methodological approach applied: a follow-up study of root canal treatments, performed in general public practice in a general population.

*External validity*

This study investigated root-filling quality and periapical status in radiographs of teeth treated before and after the above mentioned educational intervention, at treatment and \( \geq 4 \) years after treatment. Data was provided from PDS clinics, however, using a secondary source for data collection might increase the risk of loss of information, which might influence the results. There was a relatively high frequency of unavailable patient data. However, there were no differences in sex, age and type of teeth treated between patients with unavailable and available radiographs for teeth treated before and after the educational intervention.

*Internal validity*

Strict criteria were used for all variables. The mean interobserver agreement was \( \kappa = 0.89 \), which implied an overall substantial agreement.

Pre- and post-education treatments were followed for 7 and 4 years respectively. As only minor changes of the periapical status occur after 4 years (Ng *et al.* 2007, Rud *et al.* 1972, Strindberg 1956) it was concluded that comparisons between the groups were justified. However, the longer observation period might have allowed some more teeth to heal, with a favourable influence on the outcome in teeth treated in 2002 (pre-education).

Periapical status was assessed using the ordinal scale of PAI. As the PAI-method correlates the radiographic image to the histological
status it may be considered a valid method, and because the observers are trained and calibrated against the same reference radiographs, legitimate comparisons can be performed using the method. According to the method periapical disease is defined mainly as the scores 3, 4 and 5 on the five-point scale. A definition of definite AP as scores 4 and 5, has been discussed (Ørstavik et al. 1986). The effects of such a dichotomization are a higher specificity (the proportion of individuals without the disease who are correctly identified by the test) and the potential to investigate and compare more severe periapical disease in relation to treatment outcome, which a cut-off between scores 2 and 3 does not provide.

The regression analyses included independent variables used in previous research: type of tooth, marginal bone level, apical status, root-filling quality, type and quality of coronal restoration (Kirkevang et al. 2004, Ng et al. 2011a). However, overall low R-square values indicated a weak fit of the model. Therefore it cannot be completely ruled out that other factors may be associated with treatment than those investigated in the regression analysis, indicating that we need to be cautious as to the interpretation of the results.

Cost minimization analysis (IV)
In this study, data from patient records were used retrospectively by the researchers to calculate the number of instrumentation sessions. The reliability of the use of patient records must be questioned because of the risk of inaccurate recording (Labelle & Swaine 2002, Sund 2012). However, when using records data sources, there is no single best methodological approach. To a large extent the data were reliably collected, but not without potential errors. Treatments extending over several years had to be traced back in the computerized record system. Recording quality in general was somewhat low, and the investigators had to double-check the sometimes incomplete documentation against the information in the invoicing system.

In this study actual costs were estimated, but the economic measures could also have been expressed as itemized fees for service. However, in the Swedish reimbursement system, charges for root canal treatments are set independently of instrumentation technique.
and the numbers of appointments required, and therefore provide inadequate data for approximations of costs (Drummond et al. 2005, Oscarson 2006). The cost calculation was therefore based on a micro-costing approach (Drummond et al. 2005), including all instruments and medicaments for the SSI and the NiTiR technique separately, as required to clean, shape and fill a root canal. This yielded an average cost for one instrumentation session, to which staff costs were added. However, this disclosed only a proportion of the total costs, and there was the risk of overlooking some costs. For example, local supply of personnel and high quality equipment (operation microscope), may have influenced the overall treatment costs. However, we believed that all other resources remained equal before and after the educational and training program, and they were therefore excluded. It is well known that practice varies within the same type of treatment, the same clinic, the same country and across countries (Eckerlund 2001, Heasman et al. 2011, McPherson et al. 1982, Sherry et al. 1996). What justified the micro-costing approach was that actual costs are likely to be generalizable across settings (Drummond et al. 2005). Importantly, the small unit costs were of minor concern, considering that salaries for personnel (staff time) comprised the bulk of the overall costs (Drummond et al. 2005, Oscarson 2006).

A methodological problem was estimation of the length of instrumentation sessions. For obvious reasons there is no available scientific consensus as to the duration of appointments for endodontic procedures. Studies of preparation time did not prove appropriate to the purpose of the study, while estimation of treatment sessions was applicable (Bjørndal & Reit 2005, Hommez et al. 2003). In these studies most dentists needed at least two instrumentation sessions for a root canal treatment. This was in accordance with the present results and would justify our model. It was decided that instead of including an uncertain time estimate in the model, calculations should be based on an average treatment session of one hour, in accordance with standard practice in the Sörmland County Public Dental Service. To control for this uncertainty a sensitivity analysis was performed.
On results
The results will be discussed according to the main structure of this thesis: factors involved in establishing change in practice and effectiveness in practice.

Factors involved in establishing change in practice
In Study I, high quality operative procedures were reported to be standard among dentists in the two counties investigated. These findings are similar to those of an earlier investigation of routine practice among Swedish dentists (Gruffman et al. 2009). Although current routines had been explicitly reviewed in the intervention county during the educational and training program, in contrast to the control county, the self-reported routines were similar and we drew the conclusion that everyday practice had not been affected by the educational intervention.

In contrast, compliance was lower in both counties with respect to routines for better informed treatment decisions; such factors that shape the quality and the outcome of treatment (Demant et al. 2012). Pre-operative prognostic information to the patient and postoperative evaluation were not routine. This suggests that unhealed cases may remain undetected and clinicians might consider successful outcome more in terms of functional and esthetic qualities of retained teeth, than in terms of retained, infection-free teeth. This seems to be confirmed in Study III, where at follow-up, 16% (n = 35) of the teeth followed over 7 years and 16% (n = 43) of those followed over 4 years showed persistent or developed definite AP (PAI 4+5) after endodontic treatment. According to Ørstavik et al. (1986), a PAI score of 4+5 is a definite failure of treatment and in such cases either retreatment or eventually, extraction, should be considered. In some cases, the pre-treatment prognosis for these teeth may have been questionable resulting in initiation of treatment of teeth at high risk of failure. The strong correlation between definite AP at treatment and at follow-up, disclosed in the logistic regression analysis (Study III), indicates that it is difficult to eliminate root canal infection in obviously infected teeth. Even in such cases, however, postoperative control would have led to disclosure of AP, whereas in the absence of routines to recall patients for follow-up, there is a high risk that these
failures may remain undetected. The frequency of untreated larger lesions in this study is difficult to explain. One reason might be that lesions which otherwise would have remained undetected were disclosed during collection of the data for the research project. The high number of extracted teeth with definite AP, treated pre-education may indicate that failures have been detected, however the lack of available record data hampers further conclusions to be drawn.

When survey responses about reasons for adoption of new technology (Study I) were compared with the findings of the in-depth interviews (Study II), one finding common to both methods of inquiry was that formal learning (lecture) was not considered important for adoption of new routines and change of clinical behavior. This applies across professions. The low rate of behavioral change in response to theoretical knowledge is supported by findings in a large number of studies (Bonetti et al. 2006, Dopson et al. 2002, Grol & Grimshaw 2003, Forsetlund et al. 2009, O’Brien et al. 2007, Reit et al. 2007, SBU 2012). The literature offers several explanations. A major concern is that strict evidence or expert consensus may be inaccessible, or when accessible, difficult to understand. Efforts to locate, interpret and apply new findings are essential for utilization of knowledge, but relevant, robust research findings are few and have low priority in general practice (Nutley et al. 2008, SoS 2011b, SoS 2013). This was further confirmed by the experiences revealed in Study II. The importance of an expert facilitator to help identify new technology and to help assess its relevance to routine practice, was described as an important constituent for change.

Another possible explanation is that clinicians have greater confidence in their own empirical experiences than in research results or clinical recommendations, and value technical knowledge and visibility of the treatment: clinical knowledge is considered in such terms as skill and craftsmanship (Dopson et al. 2002, Ferlie et al. 1999, Grol 2007, Nutley et al. 2008). Reit et al. (2007) drew similar conclusions in a comparable study of adoption of the NiTiR technique after an educational program. Their results were based on an analysis using the Diffusion of Innovation model, which suggests certain attributes to the processes by which innovations spread (Rogers 2003). The
attribute *trialability* (the opportunity for the participant to “try out” the new technique) was found to be important for the rate of adoption. This finding is closely related to the finding in Study II, of the importance of tacit knowledge for the adoption of new routines and new techniques. Study I disclosed that one year after the implementation program, 77% of the dentists had fully adopted the NiTiR technique and subsequent organizational routines and 12% used the technique in combination with SSI. The high rate of integration was obviously attributable to factors other than formal learning.

In 2002, when the implementation program was being planned, the research group focused on a multicomponent program, which at the time was believed to achieve the best integration results (Greco & Eisenberg 1993, McGlone et al. 2001, Wensing et al. 1998). However, in more recent research, Wensing et al. (2010) concluded that it might be difficult to distinguish a single intervention from a multi-faceted intervention in more complex programs and suggested a possible, weak association between multicomponent interventions and the effect on change.

This might be better understood by the findings in Study II. It emerged that the adoption process was highly complex. Four constituents were identified as necessary for the invariant, general human scientific structure of the phenomenon. Adding more implementation elements without an analysis of their importance to the general structure would be expensive, without any proof of improvement on the effect. For example, based on the results in Study IV, we concluded that the costs for the one-day seminars, held on four occasions, probably exceeded the benefits. The rental costs for conference premises and loss of chair-side revenue, constituted almost half of the total cost of the implementation program; approximately 1 million out of 2 million SEK. Given the interdependent structure of the adoption process, acquisition and processing of new theoretical knowledge might have been achieved just as well in the multi-professional interactive seminars and supervised training courses that were held at the clinics and directed equally to all professionals. The general structure of a successful change might have been achieved more cost-effectively, by disclosing motivation through expert demonstration
of the applicability of the change, in collaboration and by individual training in the form of chair-side feedback by the clinical specialist. It is suggested that implementation programs should use low cost approaches, unless the efficiency of adding more elements is clearly stated (Grimshaw et al. 2006, Wallin 2009, Wensing et al. 2010). The same conclusion may be drawn from the present finding: any decision to use more resources, on the grounds that they will do “no harm”, will only be costly.

What constitutes successful change?
In Study II we found an invariant, general human scientific structure of the experience of the phenomenon, which could be described by four interdependent constituents; motivation, allowance for individual learning, continuous professional collaboration and a facilitating educator. The results indicate a complex relationship of qualitative aspects of the successful change process, which we consider to be valid and representative of anyone experiencing a change in clinical practice.

Is it possible to draw valid and general conclusions from the data obtained? Most health research is funded by policy bodies who wish to have some assurance (possibly from the natural science perspective) of the generalisability and validity of the findings, given the implications for practice. The issue of validity and representativeness of qualitative research has also been raised in the field of dental care (Blinkhorn 2000, Gibson 2002, Siripant 2001). Siripant (2001) made it very clear that the question of generalisability can only be answered with a discussion of epistemology in relation to participant observer methodology. The epistemological background has been discussed previously in this thesis, but in summary:

Generalisability of the results of a study can be reached in both quantitative and qualitative research methods. In quantitative research the question of generalisability will hinge on the legitimacy of the sample as representative of the “true” population, while qualitative research will disclose how well the knowledge gained, not the participants, represents the experience for anyone presented with the same or a similar social phenomenon (Englander 2012, Giorgi 2009).
Qualitative methods can also claim to be valid (Englander 2012, Giorgi 2009, Salner 1986). The understanding of a lived experience of a social phenomenon is neither objective nor subjective (using the natural sciences’ perspective), instead, according to Salner (1986), it “constitutes human experiences”. The goal for the qualitative study was to identify these experiences in order to identify valid, general principles that will help to optimize interventions.

The new knowledge that could be provided in Study II, was the interdependence of the constituents determining successful change. Change was not experienced as successful unless motivation was disclosed individually, in a process where the relevance and applicability could be confirmed individually as well as collectively, facilitated by a trustworthy educator. All four factors were essential: none could be excluded without collapse of the whole structure. For instance, academic detailing (expert provision of knowledge at outreach visits) has only a moderate effect on the adoption of guidelines (Eccles et al. 2007). In the present study, academic detailing entailed additional elements; the educator was perceived as a facilitating element, not only competent with respect to scientific knowledge but also being familiar with working conditions at the dental clinics. This was highly motivating, as the clinical applicability and the relevance of the whole intervention was thus confirmed. Furthermore, we concluded that individual training with chair-side support was considered important. In the study by Reit et al. (2007), triability (individual training) was reported to be important for dentists for adoption of the technique. In the present study, tacit knowledge, or triability, was equally important for participants with a range of responsibilities in the clinics. In general dentistry, little is known about the impact of the exposure of entire organizations, such as the entire staff of a dental clinic, to innovation programs and the subsequent process of adoption of the new technology within the organization. An interesting finding was the importance of including the staff in interprofessional collaboration for the explicit purpose of improving routines. As with the example of academic detailing, this constituent also entailed other interdependent constituents. That everyone was involved and received the same information had two
important effects: besides the importance for functioning and effective daily routines, it also circumvented the issue of motivating other occupational groups. Thus, the members of the collaborating work units were not in a position to initiate change by themselves but needed the facilitating ability and decisional power of the educator in order for successful change to occur. As the example above indicates, the focus was not on the collaboration per se, but instead on the fact that the change was made explicit to all members of the staff. Reeves et al. (2013) concluded that the effectiveness of interprofessional collaboration was probably limited. We are aware that this might also be the case in our study, and Studies III and IV were conducted for the purpose of investigating the effectiveness of the interrelated constituents. However, with respect to this and other constituents the study revealed new and important knowledge.

There are a number of studies of integration of NiTiR systems, both international (Bjørndal & Reit 2005, Parashos & Messer 2004) and national (Gruffman et al. 2009, Reit et al. 2007). In studies explicitly investigating the adoption process (John & Parashos 2007, Reit et al. 2007) it was concluded that the adoption rate was high, regardless of the educational elements. Some qualitative differences should however, be highlighted. In the study by Reit et al. (2007), hands-on training was important, and short-term integration was significantly lower when only formal lectures were provided. Post-intervention surveys have disclosed high expectations about improvement of performance, as well as the technical benefits. No study has previously investigated the process using qualitative methodology.

Our general conclusion from the results of Studies I and II is that interventional programs are costly and therefore should not focus on confirming well-functioning routines or on the dissemination of formal recommendations. The program should have as few intervention elements as necessary and a focus on few, but important, goals. We further suggest that future studies should focus on how to disclose motivation, prioritize staff retention to enhance continuing collaboration and study factors that could strengthen the personnel’s own decisional power.
Studies of effectiveness in practice
Although Studies I and II confirmed that the participants in the implementation program were highly motivated and a high rate of integration of the NiTiR technique was achieved, the most important finding in Study III was the absence of any association between more frequent use of NiTiR and an improvement in periapical status. Post-intervention, there was a significant improvement in the quality of root-filling and a significant increase in tooth survival rate. However, no positive influence on periapical status was demonstrated.

AP was found in 34% and 33% of the teeth treated pre- and post-education, respectively: higher than the 25% reported by Frisk et al. (2008) in a recent Swedish population study. We were not able to explain the higher rate, but the overall low technical quality of the root-fillings, with the associated risk of persistent root canal infection or postoperative microbial leakage may be contributing factors. Although root-filling quality improved significantly, only fewer than half of the treatments reached adequate standard at follow-up. In this context, the corresponding figures reported in two recent Swedish general population studies were 52% and 63% respectively (Dahlström et al. 2011, Frisk et al. 2008). Similar to the discussion in Dahlström et al. (2011), the finding in the present study is noteworthy and disquieting. Not only does it reveal that in more than half the cases the root canal fillings were of substandard technical quality: it also implies some degree of clinical acceptance of substandard treatment. The result is difficult to explain, but it may be attributable to general technical difficulties associated with adequate obturation.

Despite improvement in the overall technical quality of root-fillings after adoption of the NiTiR technique, as also disclosed in the study by Dahlström et al. (2011), incomplete removal of the microbial biofilm from an infected root canal can still occur. In our study the use of single-cone mode of obturation, which was more frequent after the intervention could be another explanation of a post-treatment root canal infection. Recent studies have indicated a greater tendency towards post-treatment microbial leakage with the single-cone than with the cold lateral condensation technique. However, the results are inconclusive. Comparison with studies in general popula-
tions are difficult, because of lack of uniformity in methodology: the inclusion of simulated canals in resin blocks (Gordon et al. 2005), restriction of material to extracted teeth with oval shaped canals in premolars only (Ozawa et al. 2009), curved canals only (Schäfer et al. 2012), or molar teeth only (Hörsted-Bindslev et al. 2007). Further investigation is warranted to determine whether this mode of obturation, applied in general practice, results in post-treatment microbial leakage, leading to unfavourable treatment outcome.

Taking into account the results of Studies I and II and the modest improvement in root-filling quality, a more general conclusion is that the effectiveness of spending resources on educational programs providing knowledge updates must be questioned, unless there is more systematic research, clearly focused on the current state of performance. Studies I and II disclosed that the participants expressed high motivation with respect to the new technique: this indicates dissatisfaction with the current standard of their endodontic results and a legitimate need for support to help achieve improvements. We suggest that such needs are best met by efforts to help clinicians to explicate the criteria for adequate root-filling quality, as well as the criteria for successful outcome. This requires that PDS organizations encourage and prioritize such issues as improvement in the process of arriving at well-informed treatment decisions and continuing knowledge updates.

The study design allowed for root-filled teeth to be observed after a follow-up period of $\geq 4$ years, thus, success and failure rates could be investigated and compared. Although there are few longitudinal studies available for comparison, success rates from 83% to 91% are reported (Ng et al. 2011a, Ricucci et al. 2011, Sjögren et al. 1990): in contrast, the present studies reported success rates of 68% and 67%, pre- and post-intervention, respectively. However, studies reporting the more favourable success rates were conducted on highly selected cases, under controlled conditions, not under general practice conditions. In a review of longitudinal clinical studies, Ng et al. (2007) found that success rates ranged between 68% and 85%. Comparison of studies was difficult because of lack of uniformity with respect to study characteristics, follow-up periods and criteria for success.
However, in comparable studies (mainly within Scandinavia), using strict criteria for success, a 70% success rate was reported which is in closer agreement with the present results.

In further analysis of the lack of improvement in treatment outcome, the influence on different rates of tooth survival was compared. Significantly more teeth treated post-education remained at follow-up. However, the frequency of remaining teeth with normal periapical status did not improve. One explanation for this finding is that the distribution of teeth with normal periapical status and teeth with AP was the same for the remaining teeth treated before and after the education. Factors that may influence the rate of remaining teeth, besides signs of disease, are individual treatment decisions and patients’ preferences.

In contrast to other studies, no association between root-filling quality and treatment outcome was revealed, except for treatment after the intervention. Post-treatment leakage might be explained by the mode of obturation, as discussed above, but also by the frequent use of direct composite restorations. While most were assessed as adequate, it is important to note that in the present study the restorations were assessed on radiographic appearance only, without any clinical examination, which was beyond the scope of the present study. Since patient preference for a fast single-site restoration are based mainly on financial considerations or on convenience, the choice of direct composite restorations might affect treatment outcome, and the clinical implications should be further investigated. The main finding of the regression analysis was the association between preoperative periapical status (PAI 4+5) and outcome (PAI 4+5), indicating the difficulties associated with elimination of root canal infection, even after adoption of the NiTiR technique. Of the five variables: 1) tooth type, 2) marginal bone level, 3) preoperative AP, 4) root-filling quality, and 5) type and quality of coronal restoration included in the analysis, four were in some way associated with treatment outcome, and the rather limited explanatory power of the logistic regression model indicated that factors other than those investigated may be associated with treatment outcome. Two such factors are the den-
tist’s skills and the dentist’s and patient’s preferences. However such factors were beyond the scope of the present investigation.

The findings in Study III confirmed previous findings in Swedish population studies, of a relatively high rate of AP in root-filled teeth, and failure of a high proportion of root-filled teeth to meet the criteria for overall adequate root-filling quality. With respect to treatment outcome, the adoption of a new technique, particularly developed for enhancing the shaping procedures and the sealing qualities, did not prove effective under everyday clinical conditions.

It should however be borne in mind that the underachievement of outcome needs to be interpreted very critically. The relationship between output and outcome is not straightforward. From the present results it seems that there is an underachievement with respect to outcomes, *despite* a high output. But outcome, in relation to output, cannot be concluded on the basis of the outcome measure alone (Hill & Hupe 2009, OECD 2010).

Two different perspectives emerge:

1. The NiTiR technique may be an inappropriate means of improving outcome. This does not seem to be the case. Efficacy and effectiveness studies have shown a relationship between improved root-filling quality and rational clinical routines. However, it remains to be investigated how outcome can be improved under clinical conditions.

2. Outcome may be influenced by other factors. This seems to be the case in Study III where several factors associated with treatment outcome, unrelated to the particular NiTiR technique, seem to be important for the outcome of root canal treatment.

The distinction of means and ends (outcome) is important. Conducting, for instance, clinical health goals on the basis of output may fail to improve outcome. Careful analysis of the intended change of practice is advocated in order to save resources by avoiding implementation of change that has no potential to alter outcome at all.
In Study IV, the cost-effectiveness of root canal treatment was investigated, and the results from the three previous studies were applied. The conclusion was that cost-effectiveness could be achieved by effective treatments decision, as discussed in Study I, by appropriate accrued resources for effective implementation programs, disclosed in Study II, but not in Study III, where the results showed that treatment outcome was unaffected by the change in endodontic practice. Thus only some of the objectives of the implementation program were achieved. It is concluded that the 77% adoption rate, representing a high output, did not lead to an improvement in treatment outcome. Nonetheless, new and important knowledge has emerged from the studies, which might be potentially useful for the interpretation of these results, and for future studies.

The most important finding in Study IV was that the differences in costs between the root canal treatments before and after implementation program was attributable, not to the techniques themselves, but to the different treatment regimes in effect before and after the intervention. After the change in practice, fewer instrumentation sessions were required, resulting in a saving in costs. The high adoption, and acceptance, of new routines associated with the introduction of NiTiR, as discussed in Studies I and II, probably explains this finding. A higher awareness of treatment planning and routines for the scheduling of planned root canal treatments seem to have influenced the significantly lower number of instrumentation sessions needed after the intervention; 2.82 before and 2.38 after the intervention. After the intervention, for every second root canal treatment, one session was saved. However, the estimation of cost savings assumes that the resources saved are available for alternative use, and we cannot automatically rely on savings unless we are sure that they are usefully redistributed (Drummond et al. 2005). If the saved clinical time disclosed in Studies I and IV was used for ineffective dental care, even if well-done, the benefit of the savings would be diminished, or lost. The issue of redeployment of resources is an important task for care providers and has implications for the efficiency of patient care.

Staff time was the most influential factor on all costs. This was confirmed by Oscarson (2006) in a study of preventive dentistry and by
Tan et al. (2008), in a micro-costing study of restorative dentistry. This finding is also one of the most important in Study IV. The clinical implication is that every decision made with respect to root canal treatment, suggesting additional appointments, “just to be sure”, or “in case”, unsupported by medical need or clinical recommendations, merely adds to the cost: there is no evidence of an associated benefit. The importance of well-supported clinical knowledge applies to all four studies.

It is rather surprising that no previous cost-evaluation study has been published in the field of root canal treatment. One explanation could be the substantial variation in definitions of outcome (Kirkevang 2002, Ng et al. 2007). The importance of the use of strict criteria for success and failure with respect to treatment of oral diseases has been discussed in several studies, emphasizing the need for relevant and valid comparisons of treatment success and cost-effectiveness (Jönsson & Karlsson 1990, Ng et al. 2007, Yule et al. 1985, Ørstavik et al. 1986). However, the most plausible explanation for the lack of cost evaluations is the practical difficulty of estimating costs for root canal treatments carried out under substantial practice variations (Eckerlund 2001). According to Eckerlund (2001) practice variation occurs at all levels of medical care, partly reflecting the clinicians’ attitudes. This does not mean that the care is not useful or ineffective. However, the often large variations indicate that there is room for improved medical as well as economic efficiency.

The implications of practice variation became clear when the model for a cost-minimization analysis was developed. During the data collection process, it emerged that there were substantial variations in the use of types and amounts of instrument and disposables. Thus the measurement of costs in the model is not a definite general account of the costs for root canal instrumentation and serves more as an example of how costs could be assessed. We are aware that anyone professionally involved in root canal treatment will find other necessary items, or other amount of items, more appropriate for a calculation. The current model is based on local practice routines, described in as much detail as possible, so that comparisons can be made.
Direct and indirect costs associated with the change in practice were also calculated, but not included in the CMA. There is a need for more studies using actual program costs (Grimshaw et al. 2006). By compiling the total costs of an intervention, every specific intervention element can be identified, as previously discussed in relation to the findings in Study I.

This study does not address whether root canal treatments are worthwhile. No study has included changes in quality of life in a cost-benefit evaluation assigning monetary values to both costs and outcomes, in order to disclose the benefits of a retained, symptomless, infection-free, root-filled own tooth in terms of quality of life. Improvements in oral health (retained healthy teeth) relate to changes in the physical, social and emotional functioning of patients. The scoring system for outcome of root canal treatments does not encompass such values as quality of life. In the Periapical Index method the scores on the ordinal scale have the same weight; PAI 1 has the same value as the PAI 5, but a different impact on oral health: there is no indication, for instance, of how much better PAI 1 is, compared to PAI 5 (Jönsson & Karlsson 1990, Yule et al. 1986). For such analyses more sophisticated scoring systems and cost evaluation models are required.

A perspective that was not addressed in Paper IV was that of indirect costs borne by society and the patients, for time taken off work, loss of income, and for time spent travelling to and from the clinics for appointments. Since instrumentation sessions were significantly fewer post-education, this perspective is important. If travel costs could be saved and time taken from work could be reduced, the introduction of a new root canal instrumentation technique and new organizational routines could positively affect both patient and society. Nonetheless, using the same argument as above, savings must be carefully scrutinized, because they imply that saved resources are efficiently redeployed.

Cost evaluation studies, finally, cannot account for losses in confidence in the relationship between patients and professional, in cases of failure of treatment. Failure is costly, for both the care provider
and the patient. This value is unknown, but every effort to improve outcome may be a benefit for the PDS: the confidence of loyal and satisfied patients is the core of the organization. The benefit for patients must be the perception of the quality of the treatment they have received.

Clinical implications, unanswered questions and future research

Improvements in root canal treatment outcome can only be determined if adequate and high quality data are available for scrutiny. In the interests of patient security, and also to ensure valid and reliable data for future studies, there is room for improvement in the accuracy of information in the patient treatment notes.

For the same reason interventions should use the current state of endodontic treatment outcome as a reference point for more systematic research of follow-up routines of root canal treatments.

The present results imply that a critical approach is warranted towards the inclusion of elements of formal education in future implementation programs. Considering that formal learning is largely ineffective, interventions should be based on careful inventory of routines and performances.

In endodontic treatment, any additional treatment, unsupported by clinical recommendations, is costly. We propose further studies on how to improve well-informed, efficient clinical decisions.

There is room for improvement in endodontic practice. Clinical recommendations for effective care could well be accompanied by expert help to explicate the criteria for adequate root-filling quality, as well as the criteria for successful outcome.

There remain a number of unanswered questions in the interesting field of the decision-making process in relation to clinical contextual factors in general practice endodontics.
For a comparison of qualitative research results, the results from the descriptive phenomenological method applied in Study II, and the results from a qualitative Content Analysis method, used in the same material, could be compared in a probably unique study.

Comparisons were made between root-filled teeth followed over 4 and 7 years. The different follow-up periods may be implicated in some of the unexplained findings. To improve and expand Study III, the teeth root-filled in 2005, i.e. the sample with the shorter observation period, could be investigated retrospectively in 2012, at 7 years’ follow-up, for a new comparison with teeth root-filled in 2002.

Some of the unanswered questions concern economic evaluations of root canal treatments. For the purpose of investigating the benefits of root canal treatment, for the particular patient, or for society in general, cost-utility and cost-benefit analyses would be required. While this was beyond the scope of the present thesis, it is a highly relevant topic for further research.
CONCLUSIONS

In the studies of establishment of behavioural change in practice it was concluded that:

• The comprehensive implementation program led to a successful integration of rational organizational routines and the NiTiR technique.

• A successful change in clinical practice was perceived to be attributable to a clinical relevant intervention which was introduced under collaborating and individual learning conditions by an educator with clinical expertise, which disclosed clinicians' motivation and facilitated implementation.

• The questionnaire responses differed in quality and in meaning from the qualitative experiences of changing behaviour, revealed in the in-depth interviews. A cautious attitude is recommended when comparing the results of questionnaire surveys intended to explore qualitative attitudes and experiences of change, and qualitative research methods. Unless their different epistemological positions are clearly defined, conclusions should be drawn with a critical approach.
In the studies of the effectiveness of the intervention on treatment outcome and the cost-effectiveness of root canal treatment it was concluded that:

- Root-filling quality improved significantly post-education, but there was no corresponding improvement in success rates defined as scored PAI 1+2 or in the frequency of remaining teeth with normal periapical status.
- The total tooth survival was significantly higher for teeth root-filled after the intervention.
- The use of NiTiR was more cost-effective, primarily because fewer instrumentation sessions were required after the intervention.
- The study revealed that high output is not predictive of high outcome: the replacement of one cleaning and shaping technique with another will not help improve treatment outcome as long as other related factors remain unaddressed.
Acknowledgements

Recognition of any achievement is usually the result of support of a group of people, which is certainly the case in this thesis. I am deeply indebted to all the participating personnel in the Public Dental Service in the County of Sörmland, and Västmanland, Sweden, as well as to all the patients, without whom this thesis would not have been possible.

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all compassionate friends outside my clinical work and research, who forced me to leave my desk at times,

to all my family: in Stockholm, Aalborg, Bern, Zürich and Uppsala.

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APPENDIX A: QUESTIONNAIRE

Enkät om endodontiska behandlingsrutiner

För en tid sedan sände jag ett brev om en kommande enkät. Här är den!

Enkäten ingår som en del av ett projekt med titeln: "Kvalitativa och ekonomiska konsekvenser av införandet av maskinell rensningsteknik i allmäntandvården". Den består av frågor om vardagsnära kliniska frågeställningar.

I enkäten finns det två begrepp som särskiljs:

<table>
<thead>
<tr>
<th>Begrepp</th>
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<tr>
<td><strong>Manuell rensningsteknik</strong> = behandlingar som sker för hand med hjälp av rostfria filar, eller NickelTitan-filar, och med filnings- eller reamerteknik.</td>
</tr>
<tr>
<td><strong>Maskinell rensningsteknik</strong> = behandlingar som sker med hjälp av roterande Nickel-Titanfilar i vinkelstycken eller andra motorer med reglerbart varvtal.</td>
</tr>
</tbody>
</table>


Formuläret skickar du med det bifogade frankerade svarskuvertet till FoU-enheten i Eskilstuna. FoU-enheten vidarebefordrar därefter kuverten till Specialisttandvården i Nyköping för bearbetning.

Har du frågor om enkäten så går det bra att ringa:

Telefon: 0155-245280
Eller maila till: margaretha.koch@dll.se

Med vänliga hälsningar

Margaretha Koch
Övertandläkare i endodonti
Folk tandvården Sörmland
1. Jag är: □ Man
   □ Kvinna

2. Född år: [ ]

3. Yrkesbakgrund:
   Tandläkarexamen år: [ ]
   Jag är just nu:
   □ Anställd i FTV Sörmland sedan år: [ ]
   □ Privattandläkare i Sörmland sedan år: [ ]

4. Utbildning i endodonti:
   a. Har du fått teoretisk basutbildning i endodonti genom länets endodontist?
      □ Ja
      □ Nej
   b. Har du fått praktisk handledning i maskinell teknik av länets endodontist?
      □ Ja
      □ Nej
   c. Annan utbildning i endodonti efter tandläkarexamen:

5. Arbetsprofil:
   □ Endodontiska behandlingar ingår normalt i min kliniska verksamhet
   □ Endodontiska behandlingar ingår inte eller i mycket begränsad utsträckning
     i min kliniska verksamhet

6. Vilken huvudsaklig rensningsmetod använder du?
   □ Jag arbetar mestadels med manuell teknik
   □ Jag arbetar mestadels med maskinell teknik
   □ Jag blandar manuell och maskinell teknik
7. Om du arbetar med manuell teknik, vilka är det/de viktigaste skälen? Du kan markera flera svarsalternativ.

- Jag vill kunna känna ”var jag är” och det gör jag med manuell teknik
- Jag tycker att kvaliteten på rotfyllningarna blir bra med manuell teknik
- Jag har inte fått teoretisk utbildning i maskinell teknik
- Jag har inte fått praktisk handledning i maskinell teknik
- Jag har fått praktisk handledning i maskinell teknik, men vågar inte prova på patient
- Jag är rädd för att åstadkomma filfrakturer
- Mina kollegor har avrätt
- Vi har inte gemensamt kommit överens om att ha utrustningen på kliniken
- Jag gör så lite endodonti att jag inte vill byta teknik
- Annat, nämligen

8. Om du arbetar med maskinell teknik, vilket är det/de viktigaste skälen? Du kan markera flera svarsalternativ.

- Jag var inte nöjd med rensningsresultatet av min tidigare manuella teknik
- Jag tycker att det är mindre tröttsamt att rensa maskinellt när jag jämför med manuell teknik
- Jag tycker att det går fortare att rensa maskinellt
- Jag behöver färre behandlingstillfällen för att rensa klart
- Jag tycker att det är lättare att rotfylla med maskinell teknik
- Jag tycker att kvaliteten på rotfyllningarna blir bättre med maskinell teknik
- Jag arbetar redan sedan tidigare med maskinell teknik
- Jag har börjat rensa maskinellt som resultat av den teoretiska basutbildningen i länet
- Jag har börjat rensa maskinellt som resultat av den praktiska handledningen i basutbildningen i länet
- Mina kollegor rekommenderade tekniken
- Vi har gemensamt kommit överens om att ha utrustningen på kliniken
- Annat, nämligen


9. Diskuterar du det förväntade behandlingsresultatet med patienten?

☐ Alltid
☐ Nästan alltid
☐ Ofta
☐ Sällan
☐ Nästan aldrig
☐ Aldrig

10. I de fall du inte diskuterar det förväntade behandlingsresultatet med patienten, vad beror det på? Du kan markera flera svarsalternativ.

☐ Jag känner själv inte till vilket behandlingsresultat jag kan förvänta mig
☐ Jag tycker inte att det är viktig information
☐ Patienten frågar inte efter den informationen
☐ Annat skäl: ______________________________________

______________________________

Här följer några påståenden att ta ställning till. Kryssa för den ruta som stämmer bäst med ditt arbetssätt.

11. Jag tar inledande apikalröntgenbild i en projektion:

☐ Alltid
☐ Nästan alltid
☐ Ofta
☐ Sällan
☐ Nästan aldrig
☐ Aldrig

12. Jag tar inledande apikalröntgenbilder i två Projektioner:

☐ Alltid
☐ Nästan alltid
☐ Ofta
☐ Sällan
☐ Nästan aldrig
☐ Aldrig
13. Jag använder kofferdam:

- Alltid
- Nästan alltid
- Ofta
- Sällan
- Nästan aldrig
- Aldrig

14. Jag tar indikatorröntgen:

- Alltid
- Nästan alltid
- Ofta
- Sällan
- Nästan aldrig
- Aldrig

15. Jag använder apexlokalisator:

- Alltid
- Nästan alltid
- Ofta
- Sällan
- Nästan aldrig
- Aldrig

16. Ange vilket av följande tre påståenden som stämmer bäst med ditt arbetssätt:

- Oavsett om tanden är vital eller nekrotisk strävar jag mestadels efter att rensa och rotfylla vid ett och samma behandlingstillfälle.

- Oavsett om tanden är vital eller nekrotisk väljer jag mestadels att rensa och förse med rotkanalsinlägg, och rotfyller vid ett senare tillfälle.

- Vitala tänder rensar och rotfyller jag mestadels vid ett och samma behandlingstillfälle, men nekrotiska tänder förser jag med rotkanalsinlägg.
17. Ange vilket av följande tre påståenden som stämmer bäst med ditt arbetssätt. Du kan fylla i flera svarsalternativ.

- Oavsett antal kanaler rensar jag mestadels klart vid ett och samma behandlingstillfälle
- Jag behöver oftast fler behandlingstillfällen för att rensa klart enrotiga tänder
- Jag behöver oftast fler behandlingstillfällen för att rensa klart flerrotiga tänder

Här följer tre påståenden som du ska ta ställning till. Du kan fylla i flera svarsalternativ.

18. Jag rensar och spolar med:

- Dakins lösning (buffrad natriumhypokloritlösning)
- EDTA (I gelform eller som 15 % lösning)
- Annat, nämligen ____________________________

19. Som rotkanalsinlägg använder jag:

- Kalciumhydroxid
- Annat, nämligen ____________________________
- Jag förser inte kanalen med inlägg

20. Jag rotfyller med:

- hartzkloroform och guttaperka
- sealer och guttaperka
- kall lateralkondenseringsmetod (dvs. rotfyller med guttaperkapoints och kondenserar med hjälp av spridare tills jag får en homogen massa)
- guttaperkapoints som är ≥ 4% i konicitet och anpassade för maskinell teknik
- varmguttaperka-metod
- annan rotfyllningsmetod, nämligen ____________________________

______________________________
Här följer två påståenden att ta ställning till. Kryssa för den ruta som stämmer bäst med ditt arbetssätt.

21. Jag tar slutröntgen i en projektion:

☐ Alltid  
☐ Nästan alltid  
☐ Ofta  
☐ Sällan  
☐ Nästan aldrig  
☐ Aldrig

22. Jag tar slutröntgen i två projektioner:

☐ Alltid  
☐ Nästan alltid  
☐ Ofta  
☐ Sällan  
☐ Nästan aldrig  
☐ Aldrig


☐ Jag har rutiner för att kontrollera det kliniska och röntgenologiska utseendet efter rotfyllning (Efter 1 år, 2 år eller andra tidsintervall)

☐ Jag saknar rutiner för att kontrollera det kliniska och röntgenologiska utseendet efter rotfyllning (Efter 1 år, 2 år eller andra tidsintervall)

☐ Jag kontrollerar om patienten uppgjer symtom från en rotfyld tand.

☐ Jag kontrollerar när jag ska kronförse en rotfyld tand.
Här följer några påståenden som du ska ta ställning till. Kryssa för den ruta som stämmer bäst för ditt arbetssätt.

24. **Jag känner till** att det i Landstinget Sörmland finns rekommendationer för hur akuta endodontiska fall ska behandlas.

☐ Ja  
☐ Nej

25. **Om du svarat Ja på föregående fråga - tillämpar** du de rekommendationer som finns i Landstinget Sörmland för hur akuta endodontiska fall ska behandlas?

☐ Alltid  
☐ Nästan alltid  
☐ Ofta  
☐ Sällan  
☐ Nästan aldrig  
☐ Aldrig

Plats för egna kommentarer: ________________________________

________________________________________________________

________________________________________________________

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________________________________________________________

________________________________________________________

Ett hjärtligt tack för din medverkan!
# Appendix B: Micro-Costing Model

## NitIR

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## Non-disposables

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## Medicaments

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## Restoratives

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## Total SEK (USD)

| Total SEK (USD) | (54) | 197.15 (31) | 231.2 (36) | 163.65 (26) | Mean SEK (USD) | 267 (42) | 197 (31) |
MARGARETHA KOCH
ON IMPLEMENTATION OF AN ENDODONTIC PROGRAM
Change of practice, treatment outcome and cost-effectiveness